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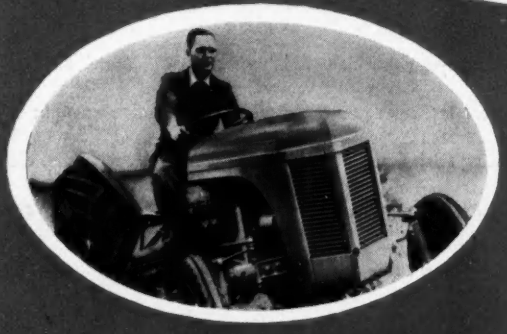

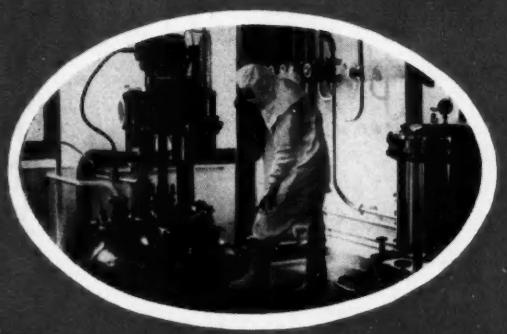

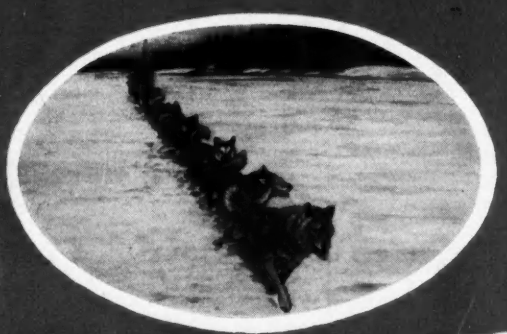

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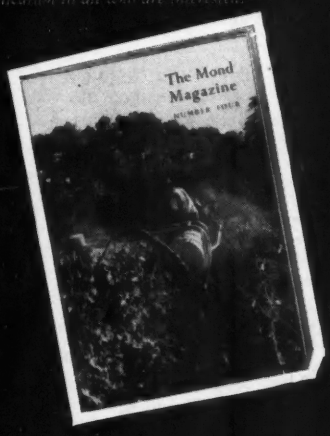

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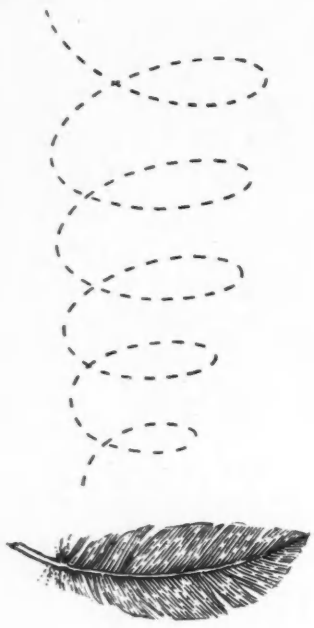

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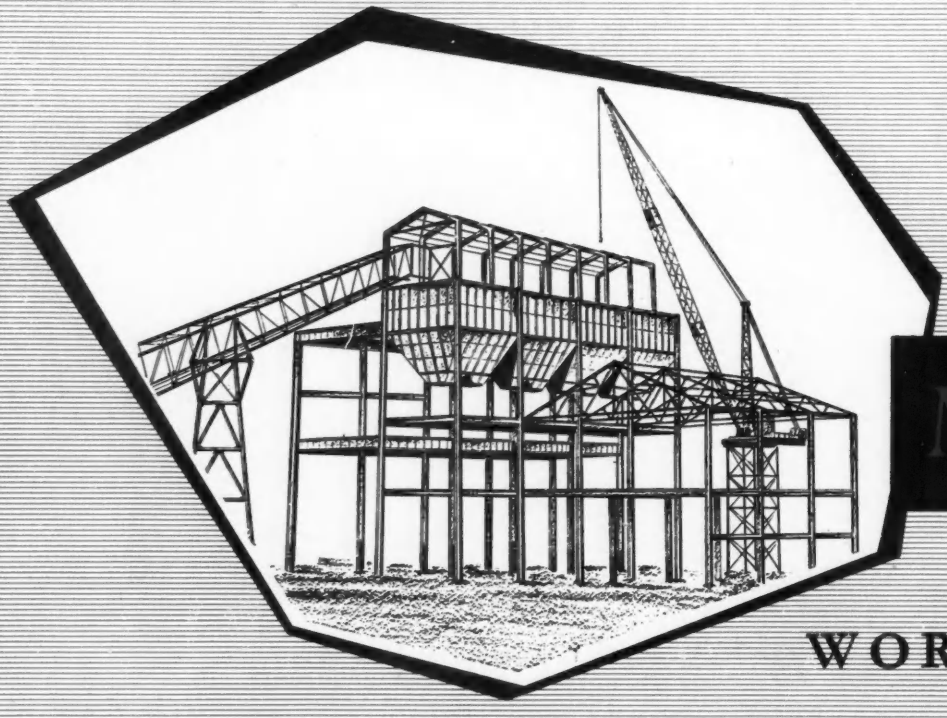

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THE ENGINEER

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ENGINEERS AND CARS

A conspicuous feature of this year's International Motor Show is the absence of new car designs of real engineering interest. There is, it is true, one car of an uncompromisingly fine quality in conception and execution, but even the presence of that vehicle, good though it is, is hardly sufficient justification in an engineering as against a sales sense, for holding an extremely expensive exhibition! The minor exhibits inspire mixed feelings. Excellent systems of, for example, suspension, are to be seen on the stands. But they are strangely absent from the completed cars. By contrast very skilful, ingenious and diligent engineering is being lavished on what seems an irrevocably obsolescent concept, the synchromesh gearbox. If, as is widely believed, the British motor industry has improved its prestige in the world, it has not improved it through the efforts of its engineers. Of course, we do not deny the important influence of public relations and salesmanship, yet it should be easier to sell a superior product, not more difficult. The most puzzling examples of backwardness in engineering design are to be found amongst British ultra-light vehicles. We suppose, sadly, it has always been accepted that the alternative to refined design is unnecessary weight. When the light vehicles of the Continent are examined we find that, with the exception of one which has a parallel twin four-stroke engine, all are designed on advanced lines, utilising to the full the latest additions to engineering technology. A conspicuous example of advanced design is an overhead-camshaft engine with a timing drive unknown in this country since the Bentley cars of the years now recognised as vintage. The discrepancy between British and Continental designs is painfully emphasised when we see an English vehicle with a solid, driven, rear axle representing no advance over the cycle-cars of the years after the first world war, and ignoring the lessons learnt by this country in dominating 500 c.c. car racing with extremely light independently sprung vehicles. The neglect of technical considerations in designing these vehicles is shown by the widespread use of carburetted two-stroke engines. Such power units are very difficult to develop, and the clear superiority of Continental designs cannot be overtaken without great expenditure and delay. Would it not have been wiser to develop here fresh fuel-injection designs? By contrast, four-stroke engines offering low specific weights and high reliability have been an unassailable *forte* of this country. Yet by an unexplained paradox the highly developed flat-twin Douglas has been withdrawn from production, while its maker continues to turn out foreign engines under licence!

The industry's apparent denial of the need for technical advance—we hope it is only apparent and that design staffs are busy on more advanced future models—has been demonstrated beyond dispute by the events which have occurred since our largest single manufacturer ceased to make 1½-litre engines. There have subsequently appeared 1500 c.c. cars which make no pretence of being designed for operation at high powers in the manner of German vehicles of this size or even our well-remembered "Javelin"; they are blatantly slow chassis with fast engines. Engineers in the industry itself must deplore without hesitation this reactionary development. But the sales side seems at present, and deplorably, to dominate the industry. For the development is recognisably the result of conditions peculiar to this country, namely, the need for very high performance at low speeds imposed by heavy traffic, and the neglect of high-speed handling qualities because short, slow journeys impose little strain upon drivers. We do not for one moment believe that it is the engineers who have failed the industry. Over-much attention is being given to low price, attractive appearance, and that reliability which can be based upon the use of out-dated, but very well explored, designs; not enough to advances in design, which, in the longer run, add still more to the saleability of the vehicle.

In view of the fact that, within the last year, professedly responsible politicians have advocated that the policy of Her Majesty's Government should not be indifferent to the needs of such a major industry, it is surprising that the president of the Society of Motor Manufacturers and Traders has refrained from pointing out how damaging that policy has been in the past. It is largely because of the heavy import duties levied by this country that the purchasers of cars in the home market are grossly ignorant of the characteristics resulting from different solutions to technical problems, and are liable to purchase a car solely on considerations of price and appearance, thus making salesmen and stylists more important to the industry than its engineers. It is possibly because Government hire purchase policy forces a vehicle to be amortised in an unrealistically short time that initial price becomes disproportionately important in the purchaser's mind, denying the manufacturer the large margin of profit needed to support research and to develop new models. It is certainly because the existence of fuel tax renders the price of fuel

utterly unpredictable that this country is lagging lamentably in the development of gas turbines and liquefied-petroleum-gas engines. It is certainly not because the Government has repudiated unequivocally the belief of the Minister of Transport and Civil Aviation that the British car is dangerously defective after two years' use in the mild conditions of this country that the cars are acceptable abroad. The technical weakness of the industry will be very material if European free trade becomes a reality. If the industry expects other countries to solve the problems it seems to make little effort itself to solve, it will pay dearly for its neglect in the future.

CEMENT, CONCRETE AND CONSERVATION

A visitor to a modern cement works cannot fail to be impressed. He is likely to see almost a copy-book installation of plant for handling, transporting and storing the various materials. Manufacture proceeds with obvious efficiency and enviable smoothness. Progressiveness is evident at once, as it is in other aspects of the industry's activities, such as the research it sponsors to promote better standards in making and using concrete. The recent introduction of a process which is new in this country's cement industry, has, however, drawn attention to the relative merits of the old and new processes. The " dry " process of cement manufacture is now being used at the Cauldon works near Stoke-on-Trent, which was described in some detail in our issue of October 11, just after its inauguration. Although new to this country, the process has been used overseas extensively for many years ; the plant essential to it has been well developed, and taking for example an item of plant such as the double-pass grate, we find there are about a hundred examples in use. The German origin of the dry process plant at Cauldon, coupled with the manufacturer's announcement that the construction of any more " wet " process works is unlikely, tempts the critic to ask whether the British industry has not fallen behind technically. And since the changeover from " wet " to " dry " manufacture is probable for all new plants, a further inquiry as to whether the changeover is the best, or only possibility, presents itself.

The overriding merit of the dry process is a saving in coal ; for each 100 tons of cement made, 25 tons of coal is used in the wet process and 15 tons in the dry process. But the latter process is also characterised by an increased complexity of plant. Obviously, over the last few years the advantage has had increasing financial weight, as the price of coal has tended to increase. The choice is not simply a balance between these two factors, however, and the raw materials available close to the district to be served by the new cement works must also be considered. British cement making has traditionally based itself on the wet process because of the abundance of raw materials—clay or mud and chalk—which are in every way ideal for that process, and which have allowed the advantageous siting of cement works serving several of the major centres of consumption. It would appear that the special conditions of the British Isles have been at least a major factor in the exclusion, in the past, of the dry process. Doubtless there are other, more complex, factors in the situation, but technical backwardness is obviously not one of them.

There remains the second point. Is there scope for other processes, or for further change ? As such change affects the quality of the cement, a perennial argument can be recalled, between the user, as represented by the engineer who is responsible for high-quality structural concrete, and the maker; the former asks for less variability in the product or, alternatively, special high-grade cement of great uniformity, and the latter points to the already satisfactory " minimum " strength value, and stresses the benefits of a standardised product. Such arguments often occur between makers and users of a variety of products, and in this case they are of only minor interest. There is, however, one other aspect of cement making which is of far wider scope, namely, the use of blast-furnace slag as one of the materials in cement manufacture, or alternatively as an additional material replacing part of the cement in a concrete mix. The special interest lies not so much in the possibility of financial gain, though doubtless some such economy accrues, but primarily in the prospect of the overall conservation of the country's resources, considering " conservation " in its widest sense. Slag is a waste material, and any use which can be found for it is obviously highly desirable, particularly where that use provides an alternative to the creation of slag heaps and to opening of quarries in an unspoiled countryside. There are, of course, difficulties. Not all blast-furnaces produce slag of the right quality, and, even where it is suitable, slag control becomes an additional duty of blast-furnace operation. Then there is the problem of siting the cement works. If it is not close to the blast-furnaces, transport of the slag may make the process too costly. Here, then, is a development which might not show any but marginal financial gain, and which cuts across the well-defined boundaries of two separate industries. So there is not much incentive within either industry to pursue it. Both of the processes of utilising slag mentioned are in fact in use in this country. But it is doubtful whether their use is on a scale which is anything like as large as could be achieved. There would seem to be good reason for intense research into the greater use of slag in these ways, and of the possibility of basing more cement works on suitable blast-furnaces. The whole subject is one which might well have been included in the Institution of Civil Engineers' recent lectures on the conservation of natural resources. The use of slag in cement, and the analogous use of fly-ash from power stations, are positive examples of the principles of " conservation " which those lectures sought to instil. Allied to that, the concrete aggregates as well as the cement are amenable to similar reasoning, and lightweight aggregates can now be made from fly-ash, and also from colliery shale. These subjects together would seem to merit the maximum encouragement of discussion which might well be fostered by a further instalment of the Institution's discussions on " the conservation of natural resources."

THE ROYAL SHOW

The council of the Royal Agricultural Society has decided that in 1960 and 1961 the Royal Show shall be held on the same site at Cambridge. This decision arises from the deliberations of a policy committee which was set up some time ago to consider the future of the Royal Show. In view of the heavy cost of erecting, dismantling and transporting the buildings needed for this large annual exhibition, the greater part of which consists of farming machinery, the committee must study whether a permanent site is desirable and, if so, where that site should be. For more than a century we have taken an interest in the engineering aspects of the Royal Show, and in the post-war decade especially we, with many others, have been able to appreciate the problems of the organisers in staging such a big exhibition in a different part of the country every year. But the many hundreds of machinery exhibitors who regularly support the " Royal " have their problems. They are naturally anxious to do the best they can for their respective businesses, and the difficulties of going to a fresh place every year cannot lightly be brushed aside. The council of the Royal Agricultural Society is wise to study all the pros and cons of the matter. A permanent site may turn out to be the most satisfactory solution, even though it would remove that fillip to local industry which is now derived from the present long-established practice of peregrination. We are glad to note that the decision to hold two succeeding shows on the Cambridge site is to be treated as an experiment only. A firm decision at this stage to have two shows on one site, and the next two on another, might well turn out to be a poor compromise from which little satisfaction could be gained either by exhibitors or visitors, or by the Royal Agricultural Society itself.

A Seven Day Journal

Engineers at Dinner

Two engineering institutions recently held their annual dinners, the one in Glasgow, the other in London. The "James Watt" dinner of the Institution of Engineers and Shipbuilders in Scotland was held on October 10. Mr. Maclay, Secretary of State for Scotland, proposing the toast of "The Institution," said that the industrial future of the country depended on adequate technological education and proper use by industry of technologically educated men. At present a relatively few rapidly developing industries employed nearly half the output of trained men. It was important to maintain the output of technologists as well as of scientists.

In London on October 17, the Institution of Mechanical Engineers held its annual dinner. The toast of "The Institution" was proposed by Sir Eric Harrison, High Commissioner of Australia. That Institution, he remarked, had been associated with the rise of the British nation to lead the world in mechanical engineering. The remarkable resilience of the nation still remained. It led the world, amongst other things, in the development of nuclear power, with which many of its members were intimately associated. He referred also to the holding in Australia next March of a conference of Commonwealth engineering institutions and mentioned how much engineering development was going on in Australia. Lastly, he asked why civil engineering contractors over here did not tender for work in Australia. In reply, Sir George Nelson, president of the Institution, said that Australia to-day produced the cheapest steel in the world, and its mechanical engineers were making great contributions to the standard of life. This country was short of the ores in which Australia was so rich. There was, therefore, all the more reason for this country to maintain close contact with Australia.

Movements of the Russian Satellite

A SERIES of careful radio observations of the progress of the Russian satellite is being made by scientists in three Ministry of Supply establishments—the Royal Aircraft Establishment, Farnborough, the Royal Radar Establishment, Malvern, and the Signals Research and Development Establishment, Christchurch. Observations commenced on Saturday, October 5, immediately after the launching of the satellite was announced. The main work is being carried out at the Royal Aircraft Establishment, where observations include angular tracking by crossed radio interferometer technique and radial velocity measurement by radio "Doppler" methods. Results that have been computed up to date indicate that the satellite's height over England varies between 125 nautical miles on evening transits and 245 nautical miles on morning transits. This difference is due to the satellite's elliptical orbits; the perigee of the ellipse occurs at a latitude of 44 deg. N., where the height is only 120 nautical miles. The maximum height reached at the apogee is about 520 nautical miles at latitude 44 deg. S. The time taken to complete one orbit is slowly decreasing by about two seconds per day because of atmospheric drag; on Sunday, October 13, the orbit's time was ninety-five minutes fifty-four seconds, and by Tuesday, October 15, it had decreased to ninety-five minutes fifty seconds. The reduction in the orbital time indicates that the mean height of the satellite is decreasing. At present this will have little effect on the minimum height, but it means that the maximum height must be decreasing by about 2 miles per day. This rate of contraction of the orbit is rather slower than would have been predicted on the basis of currently accepted estimates of the air density at these great heights. It would appear to agree with statements made by the Russian scientists to the effect that the air density must be lower than had been thought. This uncertainty about atmospheric density prevents any reliable estimate being made of the likely future life of the satellite.

Because the earth is flattened at the Poles, the plane of the orbit rotates about the earth's axis. The estimated rate of recession of the nodes is 3·2 deg. per day to the West. The precise calculation of the satellite's path from the above modes of radio observation is complex, since the curvature and rotation of the earth must be taken into account. A digital computer has been programmed at the Royal Aircraft Establishment to handle these calculations, and the results should lead to a still more accurate determination of the satellite's orbit. At the Royal Radar Establishment a crossed radio interferometer and "Doppler" velocity measuring system is also in operation. On Saturday, October 12, the satellite was observed visually at the Establishment as it passed through the zenith at 5.29 a.m. The brightness was estimated at second magnitude before reaching the zenith, but it increased to about −4, and was thus brighter than the brightest star or planet as it progressed to the south-east. A considerable amount of data is now available which should yield valuable information on the satellite's orbit and on radio propagation through the ionosphere and troposphere. The introduction of computing facilities at the Royal Aircraft Establishment should increase the accuracy and detail of the calculations to be made. All the information gathered is being made available to the Royal Society I.G.Y. Committee and other interested bodies.

The Engineer
100 Years Ago
(OCTOBER 23, 1857)

"METROPOLITAN SUB-WAYS"

"The formation of channels beneath the surfaces of roads for the conveyance of gas and water mains, and also for the ordinary drainage of streets, is a very old proposition, and one which has been repeated many times since it was first made. Every one has long felt the continual tearing up of the streets for the purpose of constructing or repairing sewers, and laying or repairing gas and water pipes, to be an intolerable nuisance, and almost every one has imagined that it was a thing very easily prevented; the most obvious method being to construct sub-ways, in which all pipes could be laid and rendered easily accessible by means of openings made at intervals from the streets to the underground channels.

"The Metropolitan Board of Works very properly took up the matter some time ago, and, in constructing two proposed new streets, determined to adopt the suggestion so often made of building sub-ways beneath them. With this view the Board, about twelve months since, decided with a praiseworthy liberality, to advertise for plans showing the best mode of laying out the surface and subsoil of streets, and the most convenient disposition of the private vaults, sewers, gas and water pipes, and telegraph wires, with any parts of the soil appropriated to other purposes. . . . . Judging by the awards, the Metropolitan Board of Works must be understood to have asked for designs for streets seventy and fifty feet wide respectively, but without caring at all whether the dimensions shown were sufficient or not, but rather considering the designs were of an elastic nature capable of being widened, deepened and otherwise stretched and distorted to meet all possible cases. . . .

"Notwithstanding the variety of arrangements which the several designs bring before us, we cannot think there are any of them which will do for the new streets. It will, however, be a very easy matter to devise a plan which will, it is to be hoped, lead the way towards the adoption generally of a system by which crowded thoroughfares will be allowed to remain at rest after once being carefully paved."

The John Scott Award

AT the general meeting of the Institution of Mechanical Engineers, last Friday evening, Sir Frank Whittle, F.R.S., who is an honorary member of the Institution, received the John Scott award. It was presented to Sir Frank by Mr. Emil A. Kekich, deputising for the American Ambassador.

The award was established by an obscure chemist, John Scott, who resided in Edinburgh until his death in 1816. He bequeathed 4000 dollars to the city of Philadelphia, the income from which was to be "laid out in premiums to be distributed among ingenious men and women who make useful inventions, but no one of such premiums shall exceed twenty dollars, and along with which shall be given a copper medal with the inscription 'To the most deserving.'" There is little information concerning the career of the donor or as to why Philadelphia should be chosen as the instrument through which the award should be made. However, after administration by the city of Philadelphia, the John Scott Medal Fund was transferred in 1869 to the care of the Director of City Trusts. From 1821 until 1834 the Philadelphia Society for Promoting Agriculture was made the agency for recommending awards and, subsequently, the Franklin Institute of the State of Pennsylvania served in this capacity. By 1917 the fund had grown to 100,000 dollars and, following authorisation by the Courts to extend the use of the fund, much larger awards may now be made, together with the copper medal. To-day, the standard award is 1000 dollars. During its history the award has been made to over 400 men and women of many nationalities. They include Orville Wright, Thomas Edison, Madame Curie, Guglielmo Marconi, Sir Alexander Fleming, and Igor Sikorsky.

British Cast Iron Research Association

THE thirty-sixth annual report of the British Cast Iron Research Association has been issued. Among the researches reported is a detailed investigation of the removal of phosphorus from pig iron. Long-term growth tests are stated to be continuing for the evaluation of cast iron in steam engineering applications. A battery of creep-testing machines has been purchased. The effects of arsenic and tin on the mechanical properties of cast iron have been studied, and

some work completed on the influence of residual elements on the impact properties of grey cast irons. A start has been made, according to the report, on a considerable programme of work to relate the mechanical properties of cast iron to the degree of nucleation of the melt. An extensive investigation has been undertaken covering all aspects of the soundness of iron castings.

Work on hydrogen pick-up from the mould, and its relation to pinholing tendencies, is said to be continuing, and the promotion of these effects by aluminium is stated to have been further confirmed. The significance of hydrogen dissolved in the melt before annealing, and hydrogen in the annealing atmosphere, has had special attention. Further work on the influence of oxygen on fluidity has failed to confirm the reduction of the latter. Pitting of ships' propellers is still being studied, with the support of the British Shipbuilding Research Association. The effects of superheating on the structure and degree of undercooling of white cast irons during freezing, the influence of trace elements on the chilling tendency of irons used in light casting industry, and other work on white and chilled cast irons, is said to be proceeding. A lengthy research on the dependence of decarburisation rate (in CO and CO_2) on graphitisation of malleable cast iron has been ended. Co-operation has continued with the British Iron and Steel Research Association in investigation of ingot moulds and bottom plates, special attention being paid to trace element effects. An experimental hot-blast cupola has been specified and ordered. The Association's dielectric heating process of sand specimens is being developed for use with higher heating rates. Much has been done on the carbon dioxide, sodium silicate process, and a number of subsidiary problems in the industrial application of the process have been studied.

The excess of income over expenditure for the year ended June 30, 1957, is reported to be £37,559, the income at £197,871 being £499 greater than that for the previous year.

Professional Engineers and the "Closed Shop"

THE Engineers' Guild is challenging a recent decision of the Edmonton Borough Council to insist upon a "closed shop" policy. The Council has ruled that all its employees, with the exception of doctors, nurses and others in similar professions, shall be members of a trade union affiliated to, or eligible for affiliation to, the Trades Union Congress; failure to comply with this condition rendering any employee liable to instant dismissal. The term "similar professions," it has been declared, is confined to dentists, health visitors and midwives, and does not apply to professional engineers.

In 1951, the Engineers' Guild successfully resisted an attempt by the Edmonton Council to impose a similar condition in connection with the appointment of a Borough Engineer. A year later, the Durham County Council also attempted to enforce compulsory trade union membership on all its staff, but it was induced to abandon the attempt following the intervention of the Joint Emergency Committee of the Professions, of which the Engineers' Guild was an active member. Commenting on the present declaration of the Edmonton Council, the Guild says that the policy of compulsory trade union membership is deeply repugnant to professional workers; the "closed shop" and the strike weapon each contain the seeds of destruction for professional status.

Theory of Shaft Whirling

No. III—INFLUENCE OF ROTOR INERTIA

By E. DOWNHAM, B.Sc. (Eng.), Ph.D., A.F.R.Ae.S.*

(*Continued from page 555, October 18*)

In Parts I and II, the whirling characteristics of a simple cantilever shaft carrying a rotor of negligible inertia were described theoretically, and some experimental results were shown to illustrate the fundamental dynamics of shaft whirling. In this article, the effect of rotor inertia and flexibility on the whirling characteristics of a similar system is described. The basic theory is extended to cover this case by the inclusion of additional gyroscopic forces arising from the rotor in the equations of motion and it is shown that the critical speed increases as the rotor inertia (but not mass) increases. In addition, whereas with negligible inertia the natural frequency of the rotating system is constant at all speeds, for a particular rotational speed, with appreciable rotor inertia, the natural vibrations will be circular, there being four resonant frequencies which vary with rotational speed. These circular vibrations are exponentially stable, and a critical whirling speed occurs only when the frequency of the forced vibration due to rotor unbalance coincides with a natural frequency of the rotating system. The critical speed and natural vibration of a system of this type were measured using the rig and techniques described previously. Comparison between theory and experiment confirms the veracity of the theoretical approach.

IN a previous article,[1] the problems associated with shaft whirling have been discussed, and some simple experiments described which confirm the fundamental theory of shaft whirling. The system chosen as a basis for this fundamental approach consisted of a cantilever shaft supported near its free end by means of a flexible bearing, and carrying a rotor of negligible moment of inertia at the free end. In this case the whirling problem is closely analogous to that of transverse vibrations of the stationary system, the critical whirling speed being the same as the natural transverse frequency. Consequently, in the past, it has been common practice to treat the whirling problem as a simple case of beam vibration. This is not the case, however, when the rotor inertia becomes appreciable as, for instance, in the aero-engine-propeller system. Here, when the shaft vibrates transversely without rotation, the inertia couple acts in antiphase with the spring restoring force, resulting in a reduction of natural frequency as the rotor inertia increases. In the whirling case, however, the inertia couple acts in phase with the spring restoring force, thus resulting in an increase in critical speed with increase of rotor inertia. As well as this effect on critical whirling speed, appreciable rotor inertia completely alters the natural vibrational characteristics of the rotating system. Whereas in the simple case external excitation of the system results in resonance at one frequency only, i.e. the natural transverse frequency of the stationary system, the whirling system with appreciable rotor inertia has four resonant frequencies for a particular speed of rotation. These circular frequencies are dependent on the rotational speed and vary accordingly; they are exponentially stable and a critical speed occurs only when the frequency of a forced vibration coincides with a natural frequency of vibration of the rotating system.

The normal unbalance whirl is excited by centrifugal forces arising from rotor eccentricity, and consequently the critical speed is reached when the rotational speed coincides with a natural circular vibration of the system. With symmetric stiffness in the system, this coincidence occurs only once in the speed range, and there is, therefore, only one critical speed for this case. It has, therefore, seldom been necessary to consider the circular vibrations to any great extent. However, in the case of aircraft power plants, due to the presence of aerodynamic forces on propeller blades, it is possible to get vibratory forces on propeller hubs at frequencies which are multiples of rotational speed and can therefore excite any of the free vibrations of the system. Consequently it becomes necessary to consider in more detail the nature of these natural vibrations. In this respect the experiments described in the following are, to the author's knowledge, some of the first of their kind.

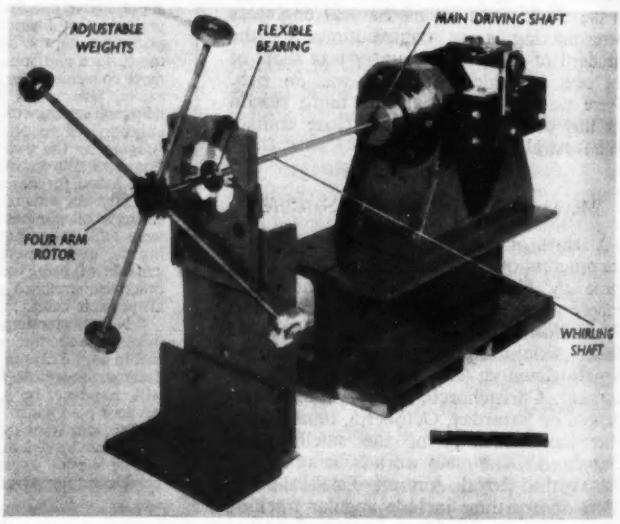

Fig. 1—Details of the model shaft rotor system

The particular system investigated (Fig. 1) consists of a rotor mounted on a cantilever

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shaft having an additional flexible outrigger bearing. Flexibility is also provided in the rotor, which consists of four flexible arms fixed in a central hub: each arm carries a brass weight which can be positioned at any desired radius. The whole system has kinetic symmetry and the moment of inertia of the rotor can be varied without changing its mass. The dynamics of the system were investigated theoretically, using methods suggested by Morris,[2, 3] the forms of vibration considered involving only shaft bending without torsion. Measurements of critical whirling speeds and natural circular vibrations were made on the model whirling rig described in the previous paper.[1]

Theoretical Investigations

The Whirling Condition.—In this case the dynamics of a shaft (Fig. 2) supported in

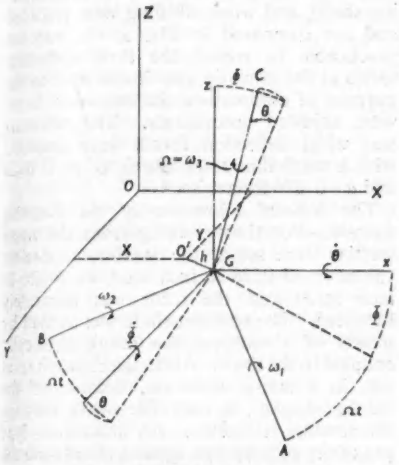

Fig. 2—The whirling condition

bearings of symmetrical stiffness carrying a load W of mass m and of appreciable moments of inertia a, a, c (c being the polar moment and a the moment about a diameter in lb in sec² units) are considered. In Fig. 2 the line OZ is drawn through O the point of attachment between the rotor and the shaft parallel to the centre line of the bearings. The point O' represents the displaced position of O having co-ordinates X and Y relative to the major (fixed) axes OX and OY. The point G represents the C.G. of the rotor, assumed to be displaced an amount h from O' in the plane XOY. The motion of the system is considered relative to the three axes Gx, Gy and Gz drawn parallel to the major axes OX, OY and OZ. The positions of the principal axes of the rotor in a general displacement of the system are represented by GA, GB and GC, the inertias relative to these axes being a, a and c respectively. The position of these axes is determined by imagining first a small rotation Φ in the xz plane about the y axis, then a small rotation θ about the displaced x axis and finally a rotation Ωt about the axis GC. The rotations Φ and θ are assumed to be small, which would be the case in practice, and Ω is the angular speed of the shaft.

The instantaneous angular velocities about the axes AG, BG and CG are represented by ω_1, ω_2, ω_3 respectively and are obtained by summing the components of the angular velocities $\dot{\Phi}$, $\dot{\theta}$ and Ω in the planes BCG, ACG and ABG respectively.

Thus

$$\left.\begin{aligned}\omega_1&=\dot{\Phi}\sin\Omega t-\dot{\theta}\cos\Omega t\\ \omega_2&=\dot{\Phi}\cos\Omega t+\dot{\theta}\sin\Omega t\\ \omega_3&=\Omega\end{aligned}\right\}\quad\ldots\quad(1)$$

The angular momenta due to the angular velocities of equation (1) are respectively $a\omega_1$, $a\omega_2$ and $c\omega_3$, and therefore the component angular momenta in the directions y to z and z to x are given by

$$\left.\begin{aligned}h_x&=a\omega_1\cos\Omega t-a\omega_2\sin\Omega t+c\omega_3\Phi\\ \text{and}\quad h_y&=a\omega_1\sin\Omega t+a\omega_2\cos\Omega t+c\omega_3\theta\end{aligned}\right\}\quad.\quad(2)$$

Substituting for ω_1, ω_2 and ω_3 from (1) in (2) gives

$$h_x=-a\dot{\theta}+c\Omega\Phi\qquad\ldots\quad(3)$$

$$h_y=a\dot{\Phi}+c\Omega\theta\qquad\ldots\quad(4)$$

The co-ordinates of G relative to the axes OX and OY will be $X+h\cos(\Omega t+\eta)$ and $Y+h\sin(\Omega t+\eta)$ respectively, where η is the angle between $O'G$ and GA and $(\Omega t+\eta)$ is the angle between $O'G$ and GX. Since h is small it may be assumed that the following forces will act on the shaft at O'.

(1) An inertia force—
$m[\ddot{X}-h\Omega^2\cos(\Omega t+\eta)]$
in the direction of the X axis. . . (5)

(2) A couple due to the change of angular momentum $-\dot{h}_y=-(a\ddot{\Phi}+c\Omega\dot{\theta})$ about an axis through O' parallel to Gy in the direction z to x. . . . . (6)

(3) An inertia force—
$m[\ddot{Y}-h\Omega^2\sin(\Omega t+\eta)]$ in the direction of the Y axis. . . . . (7)

(4) A couple $\dot{h}_x=-(a\ddot{\theta}-c\Omega\dot{\Phi})$ about an axis through O' parallel to Gx in the direction z to y. . . . . (8)

The equations of motion are therefore

$$X=-m[\ddot{X}-h\Omega^2\cos(\Omega t+\eta)]y_{11}-(a\ddot{\Phi}+c\Omega\dot{\theta})z_{11}\qquad\ldots\quad(9)$$

$$\Phi=-m[\ddot{X}-h\Omega^2\cos(\Omega t+\eta)]z_{11}-(a\ddot{\Phi}+c\Omega\dot{\theta})\phi_{11}\qquad\ldots\quad(10)$$

$$Y=-m[\ddot{Y}-h\Omega^2\sin(\Omega t+\eta)]y_{11}-(a\ddot{\theta}-c\Omega\dot{\Phi})z_{11}\qquad\ldots\quad(11)$$

$$\theta=-m[\ddot{Y}-h\Omega^2\sin(\Omega t+\eta)]z_{11}-(a\ddot{\theta}-c\Omega\dot{\Phi})\phi_{11}\qquad\ldots\quad(12)$$

where

y_{11} = linear deflection due to unit load at the point of attachment;

ϕ_{11} = angular deflection due to unit couple at the point of attachment;

z_{11} = angular deflection due to unit load at the point of attachment;
= linear deflection due to unit couple at the point of attachment.

A particular solution of equations (9), (10), (11) and (12) will be of the form

$$X=X_0\cos(\Omega t+\eta)\qquad Y=X_0\sin(\Omega t+\eta)$$

$$\Phi=\Phi_0\cos(\Omega t+\eta)\qquad\theta=\Phi_0\sin(\Omega t+\eta)$$

and substituting for X, Y, Φ and θ, in these equations gives:

$$(-my_{11}\Omega^2+1)X_0+(c-a)z_{11}\Omega^2\Phi_0=my_{11}h\Omega^2$$

$$-mz_{11}\Omega^2X_0+[(c-a)\phi_{11}\Omega^2+1]\Phi_0=mz_{11}h\Omega^2$$

from which

$$X_0=mh\Omega^2[(c-a)(y_{11}\phi_{11}-z_{11}^2)\Omega^2+y_{11}]/Q$$

and

$$\Phi_0=mh\Omega^2z_{11}/Q$$

where

$$Q=-m(c-a)(y_{11}\phi_{11}-z_{11}^2)\Omega^4+[(c-a)\phi_{11}-my_{11}]\Omega^2+1.$$

It follows, therefore, that O' will describe a circle about the axis OZ with steady motion.

Also X_0 and Φ_0 become infinite when $Q=0$, therefore, the equation

$$m(c-a)\Delta\Omega^4-[(c-a)\phi_{11}-my_{11}]\Omega^2-1=0\qquad\ldots\quad(13)$$

will give the critical whirling speeds

(where $\Delta=(y_{11}\phi_{11}-z_{11}^2)$).

If c is greater than a, which is usually the case, then only one value of Ω^2 given by equation (13) will be positive and hence there will be one critical speed only.

The Natural Vibrations of the Rotating System.—The natural vibrations of the rotating system are next considered, appropriate to the case where the forcing due to the out of balance h is absent. For these there will be a solution of the form

$$X=X_0\cos(\omega t+\eta)\qquad Y=X_0\sin(\omega t+\eta)$$

$$\Phi=\Phi_0\cos(\omega t+\eta)\qquad\theta=\Phi_0\sin(\omega t+\eta)$$

which constitute circular vibrations of amplitude X_0 and Φ_0 and frequency $\omega/2\pi$. Inserting these values in equations (9), (10), (11) and (12) with h put equal to zero gives

$$(-my_{11}\omega^2+1)X_0+(-a\omega^2+c\Omega\omega)z_{11}\Phi_0=0$$

and

$$-mz_{11}\omega^2X_0+[(-a\omega^2+c\Omega\omega)\phi_{11}+1]\Phi_0=0.$$

Eliminating X_0 and Φ_0 from these two equations gives the frequency equation

$$ma\Delta\omega^4-mc\Delta\Omega\omega^3-(a\phi_{11}+my_{11})\omega^2+c\phi_{11}\Omega\omega+1=0\qquad\ldots\quad(14)$$

y_{11}, ϕ_{11} and Δ being positive and $c>a$.

It may be shown that there are four real roots to this equation, two of which are positive and two negative. This means that for any value of Ω there will be four natural free vibrations which are circular. The negative roots correspond to circular vibrations in the opposite direction to the rotation of the shaft and the positive roots to circular vibrations in the same direction. The whirling speed occurs when $\omega=\Omega$, i.e. when the forced circular vibration due to out-of-balance has the same frequency as a positive natural vibration of the rotating shaft.

The Natural Vibrations of the Non-Rotating System.—The frequencies of vibration of the non-rotating system are obtained by substituting $\Omega=0$ in equation (14), which gives

$$ma\Delta\omega^4-(a\phi_{11}+my_{11})\omega^2+1=0$$

from which

$$\frac{1}{\omega^2}=\frac{(my_{11}+a\phi_{11})\pm\sqrt{(my_{11}+a\phi_{11})^2-4ma\Delta}}{2}\qquad\ldots\quad(15)$$

The lower of the two frequencies obtained from equation (15) is considered to be the most important for the purpose of these investigations and is given approximately by

$$\frac{1}{\omega_1^2}=my_{11}+\frac{az_{11}^2}{y_{11}}+a^2\Delta\frac{z_{11}^2}{my_{11}^3}.\quad.\quad(16)$$

The solutions given by equation (16) for a particular case has been found to be within 0·1 per cent of the more accurate solution obtained from equation (15).

Calculations Pertaining to the Experimental System

The Calculation of the Flexibility Coefficients y_{11}, ϕ_{11} and z_{11}.—The flexibility coefficients are best calculated by means of the energy method.

The installation to be considered (Fig. 3) consists of a cantilever shaft 01 carrying a

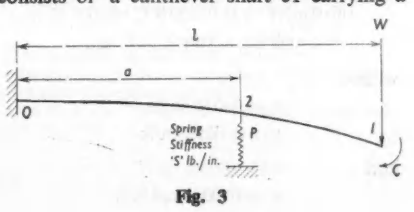

Fig. 3

load W at 1 and supported by a flexible prop at point 2. A couple C is assumed to act about point 1.

Let P be the force exerted by the flexible prop.

Let S is stiffness (pound per inch) of the prop.

Let M_{02} be the bending moment at any section of the shaft between 0 and 2 distance x from 0.

Let M_{12} be the bending moment at any section of the shaft between 1 and 2 distance x from 0.

Then

$$M_{02}=W(l-x)+C-P(a-x)$$

and

$$M_{12}=W(l-x)+C.$$

Between 0 and 2

$$EI\frac{d^2y}{dx^2}=M_{02}=W(l-x)+C-P(a-x)$$

$$EI\frac{dy}{dx}=W\left(lx-\frac{x^2}{2}\right)+Cx-P\left(ax-\frac{x^2}{2}\right)$$

$$EIy=W\left(\frac{lx^2}{2}-\frac{x^3}{6}\right)+\frac{Cx^2}{2}-P\left(\frac{ax^2}{2}-\frac{x^3}{6}\right).$$

At point 2, $y=y_2$, $P=Sy_2$, $x=a$.

Therefore

$$EIy^2=W\left(\frac{la^2}{2}-\frac{a^3}{6}\right)+\frac{Ca^2}{2}-Sy_2\frac{a^3}{3}$$

Therefore

$$\left[EI+\frac{Sa^3}{3}\right]y^2=W\left(\frac{la^2}{2}-\frac{a^3}{6}\right)+\frac{Ca^2}{2}.$$

For the actual system $a=10$in, $l=12$in, $EI=5446$ lb per square inch, $S=32\cdot89$ lb per inch.

Therefore

$$y_2=\frac{W(600-167)+50C}{5446+10952}=0\cdot0264W+0\cdot00305C$$

Therefore

$$P=Sy_2=0\cdot8683W+0\cdot1003C.$$

The work done in bending the shaft is given by

$$V=\frac{1}{2EI}\int_0^a M_{02}^2dx+\frac{1}{2EI}\int_a M_{12}^2dx+\frac{P}{2}y_2$$

$$=\tfrac{1}{2}[0\cdot0367W^2+0\cdot01050WC+0\cdot0013C]^2 \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Let

y_{11} = Linear deflection at 1 due to unit load at 1

z_{11} = Linear deflection at 1 due to unit couple at 1

= Angular deflection at 1 due to unit load at 1

ϕ_{11} = Angular deflection at 1 due to unit couple at 1.

Then due to the load W and couple C the linear deflection at point 1

$$=Wy_{11}+Cz_{11}$$

Angular deflection at point $1=Wz_{11}+C\phi_{11}$

and the work done by couple C and load W

$$=\tfrac{1}{2}W[Wy_{11}+Cz_{11}]+\tfrac{1}{2}C[Wz_{11}+C\phi_{11}]$$

$$=\tfrac{1}{2}[W^2y_{11}+2WCz_{11}+C^2\phi_{11}]. \quad . \quad . \quad (18)$$

Equating the expressions on the right-hand sides of equations (17) and (18) gives

$$\tfrac{1}{2}[0\cdot0367W^2+0\cdot01050WC+0\cdot0013C^2]$$

$$=\tfrac{1}{2}[W^2y_{11}+2WCz_{11}+C^2\phi_{11}]$$

whence

$$y_{11}=0\cdot0367\text{in/lb}$$

$$z_{11}=0\cdot00525\text{in/lb}$$

and

$$\phi_{11}=0\cdot0013\text{ rad/lb in.}$$

The Effect of Rotor Inertia on Critical Whirling Speed.—Using equation (13) in conjunction with the flexibility coefficients calculated above, the critical whirling speeds were calculated for the particular range of rotor inertias investigated in the first series of experiments described later.

The Natural Vibrations of the Rotating System.—The natural circular vibrations of the rotating system are given by the four real roots of equation (14), viz.:—

$$ma\omega^4-mc\Delta\Omega\omega^3-(a\phi_{11}+my_{11})\omega^2+c\phi_{11}\Omega\omega+1=0.$$

In order to facilitate the computation this equation may be written in the form

$$\Omega=\frac{ma\Delta\omega^4-(a\phi_{11}+my_{11})\omega^2+1}{c\omega(m\Delta\omega^2-\phi_{11})} \quad . \quad (19)$$

When the rotational speed $\Omega=0$, the frequencies of vibration of the rotor are given by $\pm\alpha$ and $\pm\gamma$, where α^2 and γ^2 are the values of ω^2 which satisfy the equation

$$ma\Delta\omega^4-(a\phi_{11}+my_{11})\omega^2+1=0.$$

If ω is plotted against Ω there will be four asymptotes given by

$$\omega=0,\ \omega=\pm\sqrt{\frac{\phi_{11}}{m\Delta}}\text{ and }\omega=\frac{c}{a}\Omega.$$

The family of curves given by plotting ω against Ω was obtained by substituting appropriate values of ω in equation (19) above and solving for Ω.

The Effect of Flexibility of the Rotor Arms on the Natural Vibrations of the Rotating System.—The calculations of natural vibrations were first made with the assumption of rigid rotor arms. An approximate allowance for the flexibility of the rotor arms was made to the calculations using a method propounded by Morris[3] in his analysis of natural vibrations of vibrating shafts with centrifugal force present (viz., the rotating propeller blade). This correction takes the form of an addition to the flexibility coefficient ϕ_{11}. For ϕ_{11} in the frequency equation (19) is substituted

$$\left(\phi_{11}+\frac{\mu_{aa}}{2}\right)\text{ where }\mu_{aa}=\frac{y_{aa}}{l_a^2},$$

y_{aa} being the deflection due to unit load at the tip of the rotor (assuming a rigid boss) and l_a being the length of the rotor arm.

The rotor inertias used in the calculations were measured using the unifilar suspension method, and the spring constants of the system were obtained by direct loading, deflections under load being measured by means of a dial gauge; the flexibility coefficients were deduced from this measurement.

Experimental Work

Dimensional details of the model rig are given in Table I.

Table I—*Dimensional Details of the Model Rig*

Effective length of shaft	= 12in
Distance of outrigger bearing from the fixed end of the shaft	= 10in
Equivalent weight of shaft	= 0·0443 lb
Weight of rotor	= 0·888 lb
Hence, equivalent end load	= 0·9323 lb
Measured spring rate of outrigger bearing support	= 32·89 lb/in
Measured stiffness of shaft alone	= 9·47 lb/in
Measured stiffness of shaft and outrigger bearing support combined	= 27·3 lb/in
The deflection coefficients are	y_{11} = 0·0367 in/lb ϕ_{11} = 0·0013 rads/lb in z_{11} = 0·00525 in/lb in
From measurements taken on the rotor	$\frac{\mu_{aa}}{la^2}$ = 0·00033.

The Critical Whirling Speeds of the System.—From measurements of whirl amplitudes at particular shaft rotational speeds, amplitude frequency curves were plotted from which critical whirling speeds were obtained over a range of rotor inertias. Measured values of critical speed are compared with those calculated in Fig. 4. The deflection forms of the shaft when statically loaded at the free end, when vibrating transversely (non-rotating shaft), and when whirling were recorded and are compared in Fig. 5. It was not practicable to record the three deflection forms at the same tip amplitudes and for the purpose of comparison the measured forms were adjusted accordingly. The vibrating and whirl deflection forms were recorded with a maximum rotor inertia of $c=0\cdot0526$ and $a=0\cdot026$ lb inch sec.^{2}

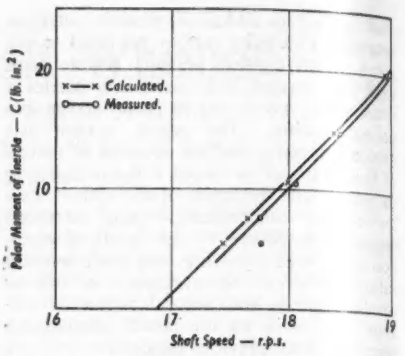

Fig. 4—The effect of rotor inertia on the critical whirling speed

The Natural Vibrations of the Rotating System.—For these investigations the rotor inertias were set at the maximum possible values ($c=0\cdot0526$ lb inch sec.^{2}, $a=0\cdot026$ lb inch sec.^{2}) and the rotor was accurately balanced. The rotating shaft was excited by means of a motor-driven crank elastically coupled to the shaft. Although the excitation was in a lateral direction, because of the inertia coupling it was effective in exciting the circular vibrations. An inductance type proximity pick-up was used to investigate the resonant frequencies of the shaft, the signal from the pick-ups being recorded from a C.R.T. by means of a continuous film camera and the frequencies measured against a 50 cycle timing trace.

The frequencies of the natural vibrations of the rotating shaft were obtained at various speeds of shaft rotation by running the shaft at a particular speed and exciting it over the frequency range of the exciter; the resonant frequencies were observed visually on a monitor C.R.T. and then recorded to give an exact frequency reading. The range of shaft speeds over which investigations were carried out was chosen to cover speeds from zero r.p.m. to a value well above the critical whirling speed of the shaft. The results of these experiments are shown plotted in Figs. 6 and 7.

The Correlation Between Theory and Experiment

The Critical Whirling Speed of the System.—Calculated critical speeds are compared with those measured in Fig. 4. There is very good agreement between measured and predicted speeds. The deflection forms of Fig. 5 show clearly the effect of the inertia couples arising from the appreciable inertia of the rotor. Theoretically, when the shaft is vibrating transversely, the inertia couple will act in phase with the displacement of the shaft and have the same effect on the system as an increase in the flexibility coefficient y_{11}, i.e. reducing the natural frequency. This is shown in Fig. 5 by the increased curvature of the transverse vibration form compared with the static deflection form. When the shaft whirls the inertia couple theoretically acts in opposite phase to the displacement of the shaft, thereby increasing the critical whirling speed; again, this is

shown in Fig. 5 by the decrease in curvature of the whirl deflection form, compared with the static form.

The Natural Vibrations of the Rotating System.—Figs. 6 and 7 show the measured natural frequencies of the rotating shaft. In Fig. 7 the measured frequencies have been plotted as they actually appeared, i.e. as definite frequencies at particular shaft rotational speeds, either in a forward or reverse sense with respect to the direction of rotation of the shaft. At $\Omega=0$ there are the two natural frequencies appropriate to the non-rotating system. When the system is rotating, four frequencies are obtained in divergent pairs from the original two. The theoretical explanation of this phenomenon may be obtained from equation (14), which gives the frequencies of the free vibrations (ω) for any rotational speed (Ω). When Ω is zero there are four roots of equation (14) given by $\omega=\pm\alpha$ and $\omega=\pm\gamma$: the negative roots of ω correspond to the reverse whirls and the positive roots correspond to forward whirls. When the shaft is rotating the roots of equation (14) are no longer symmetrical, the negative roots decrease in frequency with increase of shaft speed and the positive roots increase in frequency, the negative roots are asymptotic to $\omega=0$ and

$$\omega=-\sqrt{\frac{\phi_{11}}{m\Delta}} \text{ respectively,}$$

and the positive roots are asymptotic to

$$\omega=+\sqrt{\frac{\phi_{11}}{m\Delta}} \text{ and } \omega=c\frac{\Omega}{a} \text{ respectively.}$$

In Fig. 6 the natural frequencies of Fig. 7 are plotted algebraically, positive and negative appropriate to forward and reverse motions, respectively. Three sets of results have been plotted (ω against Ω), two calculated (one assuming rigid rotor arms and one allowing for flexibility in the rotor arms), and a set of measured results obtained by exciting the rotating system. It is seen that the lower frequencies are not appreciably affected by the flexibility of the rotor arms; the effect on the critical whirling speed of introducing arm flexibility into the calculations was found to be of the order of 1 per cent. However, the higher frequencies are affected to a greater degree, which is to be expected as the natural frequency of the rotor arms was 58 c.p.s. and the measured value of γ was 60 c.p.s. The calculated roots of the negative frequency originating in $-\gamma$ are higher than those measured when the flexibility of the rotor arms is ignored, whereas on correcting for this flexibility the frequencies obtained are lower than those measured, although the discrepancy between theory and experiment is less than in the latter case. In the case of the root originating in $+\gamma$ again the correction for rotor arm flexibility is too great for the lower rotational shaft speeds but as the shaft speed increases the two curves of calculated and measured results quickly converge as the frequency of the circular vibration becomes appreciably greater than the natural frequencies of the rotor arms.

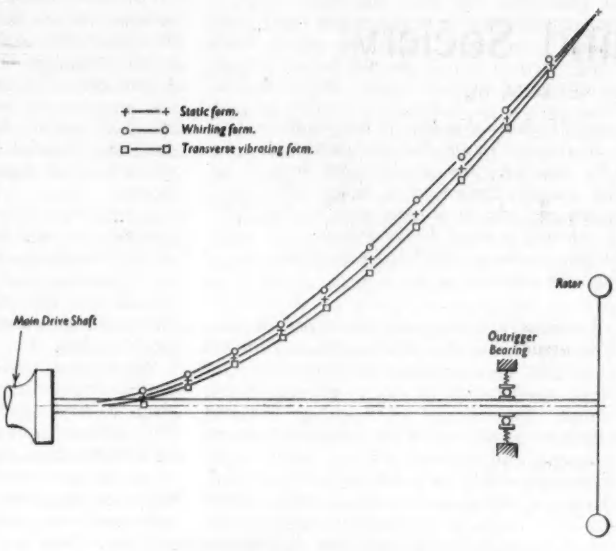

Fig. 5—Comparison of deflection forms

Conclusions

The experiments described show that, providing the constraints in a system are known precisely, it is possible to predict accurately the critical whirling speeds and the natural frequencies of the rotating system for a rotor of appreciable moment of inertia. The allowance for flexibility of the rotor arms increases the accuracy of the calculations, especially when the frequencies are appreciably different from the natural non-rotary frequencies. The method has the additional advantage that it is easily applied to the basic theory since only a change in the flexibility coefficient ϕ_{11} is required. In practice, however, the establishment of the correct theoretical approach, although essential, is by no means the complete solution to the problem. In the experimental case it was possible to make accurate calculations of the flexibility coefficients due to the relative simplicity of the elastic system, and the ease with which check measurements of stiffnesses could be made.

In the equivalent full-scale installation, however, practical difficulties make accurate estimates of the constraints in the system difficult to make; particularly as initial calculations are often made in the design stage. The whirling problem must, therefore, often be treated as a question of accurately estimating structural stiffnesses and inertias.

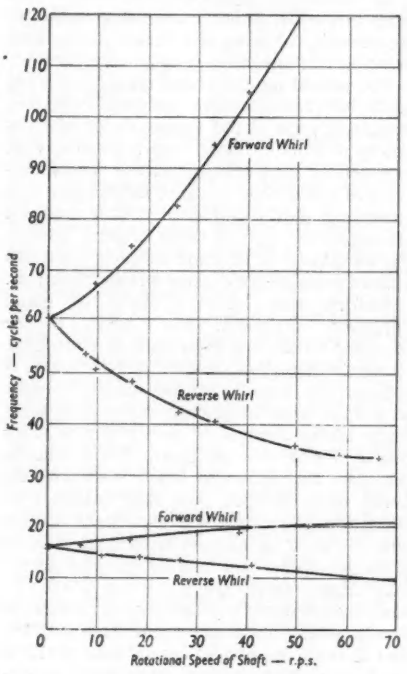

Fig. 7—Measured natural vibrations of the rotating shaft

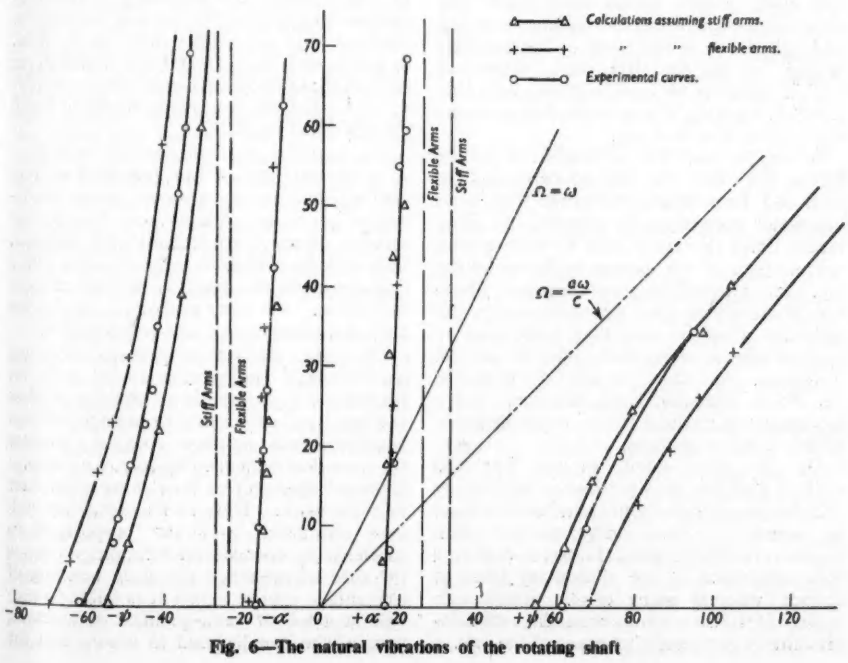

Fig. 6—The natural vibrations of the rotating shaft

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(*To be continued*)

Technology and Society

By SIR GEORGE NELSON, Bt.

In his Presidential Address to the Institution of Mechanical Engineers last Friday, October 18—here reprinted almost in full—Sir George Nelson discussed education and the numbers of technologists needed by industry. But he discussed those subjects under a light different from that usually thrown upon them. He stressed, for example, that science and technology are an integral part of life to-day, and that some knowledge of them is essential to good administration. As an administrator himself he took the line that engineers are not wasting their talents in becoming mixed up with administration.

Principles of Fundamental Importance

A VERY basic lesson I have learnt is that throughout the wide fields of engineering with which I have been associated, namely, mechanical, electrical, electronic, aeronautical, and nuclear, the most fundamental requirement is a sound knowledge of the first principles of mechanics coupled with an intimate understanding of the properties of materials. A life's experience has taught me that more problems arise in all these fields from weaknesses in mechanical design than from any other cause, impressing upon me the necessity of being well versed in the basic principles of mechanical engineering.

The second point I would emphasise is the need for collaboration between specialist experts in each of the various fields of technology. For example, most problems in mechanical engineering involve considerations of metallurgy, stresses, lubrication, and governing, and very few men have intimate knowledge of each of these subjects, so that the ultimate best solution of such questions needs the assistance of appropriate specialists.

Unfortunately, it is a habit of many designers, engineers, and others to be reluctant to disclose their lack of knowledge by consulting other people. I believe this is a disastrous outlook, for one should be ready to acquire knowledge constantly throughout one's life as changes in theory and practice over a lifetime are very great. Those who do not keep themselves in touch with progress easily drop behind. The first essential to being able to keep up with the march of time and science is an intimate knowledge of basic principles and I am forever grateful that I was taught these firmly in my youth. I sometimes wonder whether they are taught as deeply as they used to be, but I am satisfied that it is of the utmost importance that the teaching of those principles should be fundamental to the curriculum of our modern technical education at all levels. I am also sure that engineers with a sound basic knowledge in mechanics are less hesitant to consult specialists in other fields whereas those who have not this knowledge hesitate to consult other people for fear of revealing their ignorance.

From these two basic points, namely, sound knowledge of mechanics and a readiness to consult experts, stems the importance of maintaining the closest relationship between the various fields of engineering and also the need to initiate and co-ordinate research with adequate resources over a wide field, particularly in applied mechanics. Purely theoretical knowledge is not sufficient to solve the problems nor to appreciate their full significance in application. As a practical illustration of the industrial field I would point out that it is possible for a great steel works, or a chemical works or an oil cracking plant, each of which may have cost tens of millions of pounds, to be brought to a standstill by the failure of a relatively small mechanical part. Such failures too often arise from skimping designs in order to quote a low price, but this is false economy for the customer, since it causes the employment of large numbers of people to be jeopardised, output—the means of earning financial charges on the cost of the equipment—to be stopped, and the supplies to many other industries and to the public to be interrupted. These are indeed great responsibilities, which are daily borne by mechanical engineers and which should inspire them to collaborate with and consult others in the solution of their problems.

The realisation of these responsibilities to other industries has convinced me of the necessity to establish adequate research resources with which to study properly the problems associated with applied mechanics by men whose experience is not limited to the laboratory or design office but who are involved each day in contacts with the wider aspects of their responsibilities. The employment of such resources still further enhances the reputation which Britain already has for its high standard of mechanical engineering and which helps in its ability to meet competition from other parts of the world.

Technology and Society

I turn now to the central theme of my address which involves the relationship between technology and society. The rapid advances of science and technology in various ways and their increasing specialisation have tended to make engineering and science remote from everyday life. On the other hand, their great contribution to the improvement of the standards of living of people throughout the world, coupled with the vast increase in the potential power of destruction, has made society realise how much they depend on engineering and engineers to-day and will do so in the future. Thus society having in the last 100 years allowed a gulf to develop between science and other forms of learning is now beginning to realise the need to close that gap.

In ancient times the application of the use of fire, the wheel, the inclined plane and the lever and the production of power from wind and water were taken for granted. In more recent times the acceptance of science as a normal part of our culture is shown by the fact that many of the great classics of literature abound with what we would to-day call technical allusions and that great men in various spheres of life maintained an interest in science. As recently as 1890, for example, the Prime Minister, Lord Salisbury, had a laboratory at Hatfield House where he could dabble in his spare time.

On the other hand, in the last 100 years a gulf has grown between technology and the humanities which I can best illustrate by mentioning that many eminent men regularly raise after-dinner laughs by parading their ignorance of the elementary facts of science, whereas many people regard with scorn rather than amusement the technologist how is completely ignorant of the arts.

For these reasons I feel strongly that it is necessary to use the universities, the schools, the Press, radio and television and in fact all opinion-forming bodies to bring home to society generally the realisation that science and engineering are an integral part of twentieth century life and culture. In fact, they are essential to the maintenance and advance of our standard of civilisation in the future.

In this connection I should express our gratitude to H.R.H. Prince Philip for the way he encourages those interested in science and technology and so renders a very special service to the improvement of life and civilisation generally in addition to his other great services.

We cannot neglect the fact that in the Soviet Union the cultural climate has been given a very significant technological bias. This follows from the conscious decision of an authoritarian government and is backed by all the instruments of dictatorship. They have not hesitated to use their power over individuals to achieve their ends by, for instance, directing adequate numbers to teaching.

Although they have not yet caught up with the development of nations who were already in considerable advance of them culturally and materially we must recognise the progress they have made. Although we cannot and we would not wish to use the measure of a dictatorship state, for we have achieved so much in the past without such means, it is essential to ensure that we do not lose our lead. The Institution and all its members have an obligation to take such action as is necessary in their own particular fields in the interests not only of their own profession but of Britain as a whole.

It is interesting to note that among other means of persuasion the Soviet Government uses its control of all the financial and economic resources of the country to ensure that the scientists and engineers are among the most highly paid members of the population. Their position relative to unskilled labour provides a very real incentive for young people having the necessary qualities to turn to the technical professions, including science teaching.

Although in Britain the realisation of the importance of science and technology is growing rapidly there is still a great deal to be done, and it is interesting in this connection to consider the relative numbers of students studying in the different faculties. It will be seen from Table I that although the ratio of those studying science and technology to other students is growing slowly it is still only of the order of 1/2.

The acceptance of science and technology as a normal part of our twentieth century civilisation involves a great many fundamental problems. We have to consider the number of specialist technologists required, the problems of their recruitment and training and especially the question of their efficient utilisation. A further problem is that of the technical education of non-technologists.

Of these, the last is perhaps the most contentious. The greater use of technical equipment in homes automatically inspires the teaching of science to school children whatever their ultimate vocation, so that they can deal with the day-to-day needs of a technical character in their homes and later in their work. This, in its turn, may well also encourage a larger proportion to specialise in science and technology than is the case at present. The wide teaching of elementary science makes it possible to provide a pool of semi-qualified technicians, people who can be used to ensure that the

time of qualified technologists and their great gifts are not wasted on standards of work lower than is appropriate. A further benefit of the teaching of science to all school children is that future administrators will have sufficient understanding of scientific problems and methods to enable them to give greater encouragement to engineers and to facilitate co-operation between them.

In this modern technical world it is necessary for those responsible for its direction to have a wider knowledge than can be obtained solely from the arts and humanities. Cabinet Ministers, civil servants, company directors and others in positions of like responsibility need some scientific knowledge to enable them to give adequate consideration to the problems of the day, to lay down policy, to give guidance to those concerned with the technical details and to interpret their views. Only thus can they obtain respect from the various grades of technical staff with whom they work.

I think it is appropriate to say that the old saying "A little learning is a dangerous thing" does not apply in this context. So great is the advance in fields of science nowadays that even the greatest expert's learning is relatively small in fields outside his own. It is all a matter of degree.

I strongly believe that it is important that administrators should have at least a minimum of technical training although this should not make them feel themselves competent to take technical decisions. Rather it should ensure that because of their other qualities they will be encouraged to consult the greatest professional experts in the fields under consideration and should also ensure that those who have devoted their lives to mastering their special subjects receive the support and co-operation which they need. It is to the benefit of engineers that our non-engineering colleagues should have some understanding of the processes by which we reach our conclusions rather than be led to look on us as witch-doctors or practitioners in black magic.

The problem of providing basic teaching in science for non-technologists is one that has not been adequately tackled and it is one which I hope the Institution and its members will consider carefully. We are already following with the greatest interest experiments such as the general courses at the University of North Staffordshire and the latest suggestion for an Arts/Science Tripos at Cambridge. We in this Institution have also given much thought to the converse problem of ensuring that courses of study for engineers contain a proper balance of arts subjects. This is a two-way process and I look forward to its further development.

Apart from the need for everybody to have some appreciation of technical matters there is the additional need for a certain proportion of the population to study technology much more deeply—in short, to become professional engineers, and we have to consider what proportion of our scarce resources of manpower should be employed in this particular category. There must be a proper balance between the demands for professional engineers and the demands for other activities to support society as it expands and the demands must be adjusted as different situations arise.

At the end of the 1939–45 war this problem was studied particularly by the Barlow and Percy committees on both of which I sat as a member. We recommended in 1945 that the output of professional technologists from the universities should be doubled in ten years and the fact that that target, which we regarded as extreme, has been achieved is a great credit to those concerned ("Scientific Manpower," 1946; "Higher Technological Education," 1945).

We must not limit our consideration to the output of the universities, for in Britain an extremely valuable contribution is made by the technical colleges through the Ordinary and Higher National Certificate and Diploma courses. Men who have qualified in this way have played a great part in the expansion of the engineering industry in recent years, and I estimate that at least half of them obtain positions comparable with those obtained by university graduates and should, therefore, be classified as qualified technologists when considering these statistics.

In Table II I have indicated the great advances achieved whereby the number of those obtaining degrees in engineering has increased nearly threefold between 1938 and 1956, whereas the number of those completing Higher National Certificate or Higher National Diploma courses has increased nearly sixfold (Annual Reports *b*).

I would like to underline the particular virtue of technical colleges to-day. It is here that industry and the academic world collaborate in education, imparting to young men the knowledge and wisdom both of the college and of the world outside—a valuable combination of theory and practice. I can speak in the highest terms of the additional opportunities which are being provided through sandwich and other technical college courses which help to swell the stream of technologists in this way. This Institution and its sister Institutions have co-operated with successive governments on the question of non-university courses and we are most appreciative of the work being done by the Committee on Courses and Awards in Higher Technology, under Lord Hives.

I would again refer to the recommendations of the Barlow Committee in 1945 that the output of technologists from the universities should be doubled in ten years. Now that that target has been achieved what should be our next target? I would suggest two ways by which we can arrive at a new estimate; first, by comparing our own activity with that of other industrial countries, and, secondly, by considering present needs in industry for technical manpower.

In comparing the situation in Britain with other countries the figures usually quoted are those shown in Table III, and in particular wide publicity is given to the fact that our annual output of fifty-seven technologists per 1,000,000 of population compares with the Soviet figure of 280 and the American figure of 136 ("Technical Education," 1956). Personally, I believe this to be a false comparison, since our figures ignore the contributions from the technical colleges to which I have already referred, whereas the American and Russian figures include the output of such institutions. If we consider that half of those who qualify for H.N.C. or H.N.D. at the technical colleges are broadly equivalent to graduate technologists then the British figure is lifted from fifty-seven to 120 per 1,000,000, which is almost equal to the American figure, although still only half that of the Russian. This is a fair quantitative comparison, although it ignores the numbers of pure scientists and, of course, we have no means of assessing the relative qualities of the people concerned, I believe that in respect of quality we in Britain have nothing to fear by such comparison. If, however, we regard the Russian figure as being right then we should need to double our own output of technologists to compare with them.

TABLE I—*Full-Time Students in British Universities*

	1938–39	1944–45	1949–50	1953–54	1954–55	1955–56
Arts:						
Men	14,841	3,904	25,106	22,065	22,109	22,934
Women	7,533	8,770	12,137	12,608	12,996	13,713
Total	22,374	12,674	37,243	34,673	35,115	36,647
Medicine and dentistry:						
Men	11,375	9,017	13,613	12,600	12,422	12,670
Women	1,996	2,750	3,258	3,203	3,259	3,322
Total	13,371	11,767	16,871	15,803	15,681	15,992
Agriculture and veterinary science:						
Men	1,138	1,106	3,026	2,749	2,670	2,730
Women	170	292	431	370	336	313
Total	1,308	1,398	3,457	3,119	3,006	3,043
Pure science:						
Men	5,815	4,472	13,614	13,488	13,656	14,203
Women	1,846	2,311	3,303	3,483	3,671	3,930
Total	7,661	6,783	16,917	16,971	17,327	18,193
Technology:						
Men	5,199	5,036	10,709	9,891	10,438	11,226
Women	89	181	224	145	148	143
Total	5,288	5,217	10,933	10,036	10,586	11,379
Total science and technology	12,949	12,000	27,850	27,007	27,913	29,572
Total all others	37,053	25,839	57,571	53,595	53,802	55,682
Ratio science and technology to others	0·35	0·46	0·46	0·50	0·52	0·53

TABLE II—*Output of Technologists in Great Britain*

	1938	1956
University degrees in technology	1225	3040
H.N.C. and H.N.D. in engineering from technical colleges	911	6355

Table I shows all students at university, whereas Table II shows only those completing courses.

TABLE III—*Output of Technologists in Various Countries*

Total graduates in 1954 per 1,000,000 of population

	Engineering	Pure science
U.S.S.R.	280	56
U.S.A.	136	
Federal Germany	86	
Switzerland	82	48
France	70	
Italy	39	
United Kingdom	57	105

NEEDS OF INDUSTRY

Turning now to the needs of industry, a joint report was published in 1956 by the Ministry of Labour and National Service and the Advisory Council on Scientific Policy which estimated that industry was about 30 per cent short of the numbers which they believed would be necessary by 1959. (This is an overall figure—for mechanical engineers alone the figure is 33 per cent ("Scientific and Engineering Manpower," 1956).) Allowing for losses from death, retirement, and emigration, I calculate that an annual input of double the present figure would be required to sustain a technical working population 30 per cent greater than at present. Thus, both these methods of calculation, although rather rough and ready, indicate that the target output for scientists and engineers from the universities and technical colleges should be double the present figure. The Advisory Council on Scientific Policy set a target for this to be achieved by 1970. Personally, I would like to see it reached much earlier.

I must, however, enter a warning at this point. In the decade after the 1939–45 war we doubled the output of technologists and I

am now advocating that it should be doubled again. But this process cannot continue indefinitely; after all, if we doubled the output every decade we should reach a situation in less than seventy years in which the entire population would be technologists. In fact, it has been estimated that only about 5–7 per cent of school leavers are capable of obtaining real benefit from a university education and, if we consider that not more than one in every two or three should be a scientist or applied scientist, this means that potential technologists comprise about 2½ per cent of each age group. Since the present output accounts for about 1 per cent of school leavers, doubling it would bring us near to saturation point. Although the demands of our technical civilisation must grow as the world population and their standard of living increase, it is not possible for the number of technologists to grow anything like as fast. Therefore the efficient utilisation of technical manpower is an essential prerequisite of any increase in our standard of living.

Effective Use of Technical Manpower

It is sometimes claimed that technical manpower is wasted because scientists and engineers spend too much time on committees and administrative work and not enough on the laboratory bench and the design board. This is an extremely difficult problem to resolve but I believe part of the solution lies in the broader education to which I referred earlier. If the administrators knew more of the principles of scientific methods and the vocabulary of engineers, and if the engineers understood more of the rudiments of economics and possessed the ability to express themselves in clear English, these two groups could do their work without spending many hours in committee trying to explain their points of view to each other.

We have to realise, anyway, that engineering and administration are much more mixed together than they were years ago. In the past the great decisions of policy that affected the world were often primarily political or economic, and could be settled by those trained in the arts and humanities without reference to technical experts. To-day the major decisions of policy almost always involve technical considerations. Take, for instance, policy regarding the proper balance between nuclear and fossil fuels. This type of question can be decided only with the proper appreciation of the intricate questions involved, and when the policy decision is taken it obviously affects the direction and control of technical work. Therefore, this kind of policy decision nowadays inevitably involves long, detailed and complex consultations with technical experts which take up much time with meetings and discussions. The engineer cannot be shut away in his design office or his laboratory but must be at the heart of these discussions and must play his full part in the management of this twentieth century technical civilisation which he has done so much to create.

On the other hand, scientific work itself involves many more administrative problems than used to be the case in the past. James Watt could watch his kettle boil, Faraday could undertake his fundamental research on induction with small pieces of wire and a bucket, and even in this century Cockcroft and Walton have achieved much pioneering work on atomic structure with comparatively simple apparatus. Modern research, however, involves great teams of scientists and engineers with large supporting staffs whose direction requires the chief scientist or engineer to show at least as much administrative ability in co-ordinating the different personalities and potentialities involved as it requires scientific skill.

To take one example, the great radio telescope which Manchester University has built at Jodrell Bank is essentially for pure research in fundamental knowledge with no obvious applications in mind. Nevertheless, it is a most complex piece of mechanical and civil engineering and its completion is as much a tribute to the administrative skill of those involved as to the scientific foresight of those who conceived the idea. Another example which springs to mind is the work of the Geophysical Year. It has been realised that the expansion of our knowledge in many fields is beyond the ability of one man or one team and the advancement of knowledge can proceed only by the accumulation and co-ordination of facts and figures simultaneously from observers and research workers in all parts of the world. Here again the success of this work demands as much administrative skill as it does scientific ability. For all these reasons we cannot regard the fact that scientists and engineers spend more time on administrative work than they did in the past as being wasteful of their time and ability; rather we must regard it a symptom of the development and the increasing complexity of life.

A more significant form of waste is that which is involved in spending immense sums in training men of first-class calibre and then employing them on work where they are not making the greatest possible use of their knowledge and personal gifts. There are too many instances in Britain to-day where qualified men are starved for junior assistants or adequate tools and are used on work which less qualified men could do. There are many cases where a team of 5–6 qualified engineers is doing work which could just as well be done by one first-class engineer given an adequate supporting staff of technicians.

In the last fifty years a tremendous advance has been made in the field of industrial engineering by work study and other techniques culminating in the present tendency towards automation (a dreadful word). We have achieved enormous increases in the productivity of shop-floor labour by deskilling the work of craftsmen and by the use of machines; and by proper organisation of work, output has risen enormously. Surely it is equally important to effect comparable economies among professional engineers. I believe that in the next fifty years the revolution which has taken place on the shop floor has to be paralleled in the laboratory and the design office. This has started already by such means as the development of the digital computer designed to carry out calculations which would otherwise involve the time of many highly qualified mathematicians. Such computers are now beginning to relieve engineers in the field of aeronautics and the design of rotating machinery, but we are only on the fringe of a great field where it should be possible to achieve substantial economies in the use of qualified engineers by the greater use of computers. By the "deskilling" of work to enable more to be done by technicians, and by proper organisation, we should be able to increase the productivity of our professional engineers many, many times.

In this respect I believe much greater attention must be given to the whole problem of engineering technicians in industry. The indications are that they are in even shorter supply than professional engineers and technologists. I am most proud to be a member of the Governing Body of the City and Guilds Institute and for so many years to have sat on their committee which has given a great deal of thought to the courses and qualifications for technicians, but I do not propose to deal with this matter in detail to-night as in this Institution we are primarily concerned with professional engineers.

Similarly, we should give more thought to the employment of women in engineering. Because we cannot readily imagine women engineers in, say, shipyards, we should not ignore the possibilities of using them in other types of industry, in drawing-offices or research laboratories and many other roles. Apart from fully qualified women engineers, I believe there is great scope for developing the equivalent of the shorthand typist or secretary in engineering, that is a female technician trained in a fairly narrow field who can, nevertheless, provide valuable assistance to senior engineers and so relieve them for more important work.

One of the greatest problems with regard to the efficient utilisation of technical personnel is that associated with tendering for great engineering projects. All my life it has been a nightmare to me that firms such as mine are constantly submitting tenders which may cost as much as £20,000–£30,000 to assemble, of which only 10 per cent result in orders. The waste involved in the 90 per cent of unsuccessful tenders throughout the whole of our great engineering industry is colossal. It is bad enough in terms of money but far worse than this is the effect in terms of technical manpower.

Unfortunately, this problem is so beset with political considerations that it is hard for it to be considered in an unprejudiced atmosphere, but I feel that it is incumbent upon members of this Institution, and indeed all professional engineers, to see that this problem is thoroughly and objectively studied by public authorities, consulting engineers, and others concerned. It is largely a matter of confidence to ensure that there is no question of exploitation involved but to provide means whereby the purchaser and supplier can work out the most efficient, cheapest and satisfactory way of doing the work without involving a waste of technical effort. I feel that this problem of excessive competition for the sake of competition is the greatest factor in the waste of technical manpower. Unfortunately, warnings given in the national interest on this subject are so often misconstrued as special pleading for selfish ends and that is why I do sincerely ask for this subject to be thoroughly investigated in an unprejudiced atmosphere with a view to eliminating this waste.

Conclusions

If I may summarise the main problems to which I have drawn attention in this address, these are first the need for greater collaboration and understanding between people in all walks of life, of engineers and non-engineers, and the adaptation of our educational system to improve that mutual understanding; secondly, the need to recruit and train adequate numbers of technologists to meet the ever-increasing demands on engineering; and, thirdly, the need to secure the most efficient utilisation of our technical manpower. The underlying reason that all these problems are urgent is the fact which I examined in detail in my address to the Institution of Electrical Engineers in 1956 (Inaugural Address, 1956): it is that mankind has been prodigious in the use made of the mineral reserves of this planet in the last 100 years without any thought whatever for their replacement. Partly for the benefit of mankind through rising standards of living and partly for the destructive purpose of war, we have consumed enormous quantities of materials and, unless and until we can devise the means of

replacement, retribution will be swift and sure. New sources of materials must be found by technological means whether by transmutation or photosynthesis, by extraction from sea-water or low-grade ores, or by the recovery of scrap. These are problems which, with many others, face mankind in the very near future and which require more engineers, more technological skill, and a far greater degree of collaboration between specialists in many different fields.

In considering all these problems, I feel there has been insufficient detailed study of the fundamentals and that more research is required to enable us to seek solutions founded on definite facts rather than on theoretical generalisations. I present these problems which need urgent solution rather than dwell on the problems with which I have been concerned over the last fifty years, for I believe that the future is more interesting and more exciting than the past. A realisation of the unsolved problems of the future should be a greater inspiration to our young men than the history of the problems which have been solved. Science and engineering have given this generation the key to a future full of far more promise than that of their forebears. It is up to us to see that these opportunities are seized and this depends upon our ability to tackle expeditiously the problems to which I have referred.

In the past the British people and British engineers in particular have accepted and overcome similar challenges and in so doing have contributed in great measure to the development of the whole world. I believe that this Institution and its members, regarding our work as a calling and not merely as a means of livelihood, will accept these latest challenges and will thereby contribute to the benefit of mankind everywhere.

Recent Developments in British Naval Main Propulsion Steam Turbines*

By the late F. J. COWLIN, O.B.E., M.I.Mech.E., and A. F. VEITCH

No. II—(*Concluded from page 558, October 18*)

This paper shows the considerable advances made in British Naval main propulsion steam turbines since the end of the 1939/45 war. These advances include improvements in design and manufacture which have enabled higher steam conditions to be utilised, the overall result being improved performance which, together with weight and space reduction, results in increased endurance. The initial impetus resulted from wartime experiences and led to the three designs of "Daring" turbines, one of which is discussed. The next step was an investigation into all the factors affecting performance, endurance, &c., and the various problems and resulting improvements are discussed in that section of the paper dealing with "Y.E. 47A." The "Y.E.A.D. I" turbine design is a further development of the "Daring III" design following the "Y.E. 47A" investigations. The special requirements of the anti-submarine frigates required turbines which incorporate some rather unusual design features and they are described under the heading of "Y.100," together with shore and sea trials results.

"Y.E.A.D. I"

As a result of the "Y.E. 47A" investigations, the Admiralty put in hand work connected with a research and development programme on two alternative schemes. The first of these involved design, manufacture and shore testing of a set of main machinery based on the preliminary design prepared for "Y.E. 47A," scheme (*b*). The second was in the nature of a long term project as it was based on "Y.E. 47A," scheme (*e*). These two schemes, known as "Yarrow, English Electric, Advanced Designs," were shortened to "Y.E.A.D. I" and "Y.E.A.D. II," respectively.

In 1950 the English Electric Company was entrusted with the design and production of a prototype set of "Y.E.A.D. I" turbines and condenser.

The turbines were to produce 30,000 s.h.p. when supplied with steam at 550 lb per square inch absolute and 825 deg. Fah., the vacuum at exhaust being 26·5in Hg (Bar. 30in), with a cooling water temperature of 55 deg. Fah. The inlet steam temperature between 5 per cent and 60 per cent power was 925 deg. Fah. but was reduced to 725 deg. Fah. over the whole power range for purpose of manœuvring. The turbines, however, must be capable of manœuvring for short periods with steam at 925 deg. Fah. Above 60 per cent power the inlet steam temperature is 825 deg. Fah.

The astern turbine was to be designed to produce 7000 s.h.p. when supplied with steam at 530 lb per square inch gauge and 725 deg. Fah. and to be capable of operation with a steam temperature of 925 deg. Fah. for periods not exceeding two minutes' duration; with steam at 825 deg. Fah. full power astern power duration was specified as fifteen minutes.

The machinery was to be designed for a total working life of 40,000 hours, the life at full power being 1000 hours. A good performance was very important between 20 per cent and 40 per cent power.

The turbines had to be designed to provide simple and safe control and manœuvring from approved positions by unskilled personnel. It was therefore desirable that the ahead turbines should be operated by a single handwheel at each control position, with another single handwheel to operate the astern turbine similarly.

H.P. and L.P. Cylinders.—Service experience had proved the principles upon which the "Daring III" design was based to be sound and as the performance requirements of "Y.E.A.D. I" were similar, it was logical to adhere generally to the same design—a two-cylinder, cross-compound arrangement comprising an all-impulse design of h.p. cylinder with a solid gashed type rotor, and a double-flow l.p. cylinder with an astern Curtis wheel at each end also incorporating a solid gashed type rotor.

Steam Chest.—The steam chest is cast integrally with the h.p. cylinder.

Valve Gear.—The valve gear is different from that for "Daring III," being cam operated for both opening and closing of the three nozzle control valves and the overload by-pass valve. Each of the control valves supplies steam to individual nozzle groups designed to provide powers of 20, 40 and 60 per cent. All valves, including that for control of the astern turbine, are of the spherically seated venturi type. These valves are designed for a high steam velocity at the valve seat and throat, with a diffuser exit from the throat. The diffuser serves as a velocity to pressure conversion tube, making it possible to use a relatively small valve whilst maintaining a small pressure drop through the valve.

Two handwheels are connected to the valve gear operating mechanism by means of bevel gears and shafting, one for ahead and the other for astern operation.

From a section through the steam chest and two of the control valves it will be noted that the overload by-pass valve incorporates a pilot valve to facilitate opening of the valve by reducing the unbalanced steam forces. A similar arrangement is fitted to the astern control valve.

Materials.—Both h.p. and l.p. rotors are of 3 per cent chrome-molybdenum steel to Admiralty Specification No. 3 F.1.

It was felt that if, as a result of damage, the turbines were flooded with sea water, the effect on the blading due to chloride attack would be insignificant compared with that of the ship as a whole. In view of this it was decided to revert to stainless iron which possesses the qualities of resistance to corrosion, ease of machining, high internal damping factor and a similar coefficient of expansion to that of low alloy steels; consequently, all moving blades are made of high-tensile stainless iron and all shrouding is made of the same material.

All fixed blading is of stainless iron and with the exception of the last two stages takes the form of nozzles machined from the solid, a built-up construction being employed whereby the segments are attached to mild steel centres or centres of ½ per cent molybdenum steel where high steam temperatures make the latter desirable.

The h.p. turbine first-stage nozzle plate is machined from the solid, the nozzle segments being integral with the centre.

The last two l.p. diaphragms are made of cast steel with stainless iron nozzle division plates cast in.

The h.p. cylinder and astern inlet end castings are made of ½ per cent molybdenum-vanadium steel, but other castings not subjected to high steam temperatures are made of plain carbon steel.

The condenser shell is of fabricated steel construction, underslung from the bottom half l.p. cylinder.

The tube plates are made of rolled naval brass in 1in minimum thickness.

The tubes, ⅝in outside diameter by 19 S.W.G., are of 70/30 cupro-nickel secured by Crane Wilkie cone type packings at the inlet ends and Crane full box type packing at the return ends without the use of ferrules.

The combined water boxes and end covers are made of gunmetal, the surfaces in contact with sea water being coated with steel applied by spraying; this treatment dispenses with the steel corrosion plates or rods which would otherwise be fitted to the tube plates.

To minimise weight and space the condenser was designed for full power water velocity through the tubes of 10ft per second, which is a considerable increase on normal practice.

Performance.—"Y.E.A.D. I" machinery is about to undergo full-scale shore trials at Pametrada, and Table VII summarises the estimated performance figures when operating in temperate waters:

TABLE VII

Power s.h.p.	6,000	11,540	17,100	30,000
Inlet steam pressure, lb per sq. in abs.	710	698	680	565
Inlet steam temperature, deg. Fah.	925	925	925	825
Circulating water quantity, g.p.m.	13,250	27,300	27,400	27,200
Vacuum in Hg. (Bar. 30in) C.W.T. 55 deg. Fah.	28·57	28·69	28·28	26·5
Gear efficiency, per cent ...	95·4	96·4	96·9	97·2
Steam consumption, lb per s.h.p. hr	6·684	6·273	6·360	7·63

The following figures summarise other salient features of the "Y.E.A.D. I" turbines, and enable comparisons of weight and space to be made with the designs described earlier in this paper:—

TABLE VIII

Weight of h.p. turbine complete with valves, pipes, &c., tons	—	10·5
Weight of l.p. turbine complete with valves, pipes, &c., tons	—	18·5
Wet weight of condenser, tons	—	21·0
Specific weight of turbines in lb per s.h.p.	—	2·16
	H.P. cylinder	L.P. cylinder
Rotor bearing centres	4ft 9·9in	7ft 9·4in
Maximum speed light draught, r.p.m. ...	8020	6220
Maximum stress at rotor bore, tons per sq. in	15·9	18·7
Temperature of rotor under maximum stress, deg. Fah.	560	260

* The Institute of Marine Engineers. October 8. Abstract.

"Y.100"

Following the comprehensive investigation into the possibilities of effecting improvements in naval propulsion machinery which has already been described under the heading of "Y.E. 47A," the Admiralty became interested in the possibilities of an anti-submarine frigate of some 2000 tons displacement, to be installed with main machinery of 30,000 s.h.p. on two shafts. A speed sufficient to deal with modern submarines was required, together with a very long endurance at speeds in the region of 15 knots.

The Director of Naval Construction had stated that such a ship could only be achieved if the combined weight of propulsion machinery and fuel did not appreciably exceed 660 tons. This requirement demanded a very substantial advance in weight, space and efficiency standards. Based on the "Dido" class cruiser machinery of 15,000 s.h.p. per shaft the reduction in weight would have to be approximately 33 per cent with a corresponding reduction in space if the requirements were to be fulfilled.

A preliminary specification for the main propulsion machinery was issued in 1949, and from the resulting tenders, that submitted by the English Electric Company was considered by the Admiralty to be the most suitable; the contract was therefore placed for one set of prototype machinery to undergo full-scale shore trials at Pametrada.

The following description outlines the essential design features of the "Y.100" turbines as fitted to the "Whitby" and "Blackwood" class A/S frigates.

Specific Requirements.—(*a*) The full power of 15,000 h.p. per shaft to be obtained when supplied with steam to nozzles at 450 lb per square inch gauge and 825 deg. Fah., the vacuum at exhaust being 23in Hg. with a cooling water temperature of 85 deg. Fah.; (*b*) the ahead turbines to attain a high efficiency at all powers between 5 per cent and 100 per cent; a good performance over the range of 5 to 20 per cent is particularly important. (*c*) The astern turbine to produce 5000 s.h.p. under both tropical and temperate conditions. (*d*) Weight and space to be kept to a minimum. (*e*) Simplicity of manufacture for quantity production. (*f*) Avoidance of relatively scarce materials.

Effects on Design of These Requirements.—(*a*) The low vacuum enables a comparatively short last blade to be used thus easing problems of root stresses, therefore permitting higher rotational speeds than would be possible with a higher vacuum. (*b*) Makes it essential to provide some form of arrangement incorporating a cruising turbine; a requisite number of nozzle control valves minimises losses due to throttling at intermediate and low powers. (*d*) The comparatively poor vacuum reduces considerably the weight and size of the main machinery, particularly the condenser. (*e*) Number of different items kept to a minimum, with machining tolerances as large as possible consistent with interchangeability requirements and requisite fits of the various components. (*f*) High percentage alloy steel to be avoided where possible.

Factors Affecting Cruising Turbines.—The "Y.E. 47A" investigation has already shown that when a good performance at both low percentage power and full power is required, a machinery arrangement incorporating a cruising turbine is desirable. This was corroborated by the preliminary investigation work on "Y.100." It became obvious also that a declutchable cruising turbine possesses considerable advantages over one that is permanently coupled. A declutchable cruising turbine also effects an appreciable saving in weight and space due to the design being based on a maximum speed corresponding to some predetermined part load, whereas if permanently coupled the turbine must be designed to withstand the stresses encountered at the higher speed corresponding to the full power.

General Arrangement.—The turbine arrangement comprises a cruising turbine situated outboard of the main turbine connected through a clutch and a single reduction gear to the primary train of the double reduction gearbox. The main and astern turbines are combined in the same casing and coupled to the primary train of the double reduction gears. The main turbine and condenser are integral, the bottom half of the turbine casing forming the top portion of the condenser shell.

Economy in operation at cruising speeds is achieved by the use of the cruising turbine (exhausting to the main turbine by-pass belt) which is engaged for all powers up to approximately 33 per cent and by the transference of all load to the main turbine at powers above that point. The change of load from one turbine to the other is carried out by means of the manually operated nozzle control valve mechanism in conjunction with the clutch, which automatically engages and disengages the cruising turbine at some predetermined point in the power range established during design as being that where the efficiency of the cruising turbine falls below that of the by-pass stages in the main turbine. The main and cruising turbines are controlled throughout the entire power range by means of a single handwheel.

A rolling steam supply sufficient to turn the cruising rotor at about 400 r.p.m. is incorporated in the first nozzle control valve which prevents rotor hogging when the cruising turbine is disengaged.

Overspeeding of the cruising turbine is prevented by the emergency stop valve which automatically shuts when tripped by the shock proof emergency overspeed governor or by the hand trip lever.

Cruising Turbine.—The cruising turbine, an all-impulse design, comprises a two-row Curtis wheel followed by eight single impulse stages.

A gashed type rotor with discs machined from the solid forging carries the moving blades.

The steam chest is cast as an integral part of the top half casing and contains the emergency stop valve and four mechanically operated nozzle control valves, each of which supplies steam to individual nozzle groups.

The exhaust steam is led through two cross-over pipes into the fifth stage of the main turbine.

All diaphragms are of built-up construction, the nozzle segments being machined from the solid and fixed to mild steel centres into which the gland sleeves are dovetailed.

The first-stage nozzle plate, with its four groups of nozzles, all in the top half, is machined from the solid, the segments being integral with the centre, thus minimising steam leakage.

Main Turbine.—The main turbine comprises a single-flow cylinder with a gashed type of rotor of eight single impulse stages and an astern two-row Curtis wheel. The ahead and astern cylinders, together with their common rotor, are incorporated in a fabricated casing which, in turn, is built integrally with the condenser shell.

The astern cylinder is flexibly mounted on radial pins and supported on an extension of the aft end gland housing.

A deflector ring fastened to the astern cylinder reduces losses and minimises blade vibration by ensuring that exhaust steam from either cylinder does not impinge on the last blade of the other.

The steam chest is cast integrally with the top half cylinder and houses the four nozzle control valves, each of which supplies steam to the individual groups of nozzles.

The astern control valve chest is mounted on the exhaust end and is bolted to the flange of the astern steam inlet branch.

The diaphram of the first seven stages are of built-up construction similar to those of the cruising turbine, whereas the last diaphragm consists of a cast steel centre with preformed division plates cast in.

The first-stage nozzle plate with its four groups of nozzles is of built-up construction and bolted to the top half cylinder, steam admission being to the top half only.

The full admission astern nozzle plate is machined from the solid.

Materials.—Both cruising and main rotors are of 3 per cent chrome-molybdenum steel to Admiralty Specification No. 3 F.1. All moving blades, shrouding and lacing wires, where fitted, are of stainless iron. All nozzle segments are of stainless iron attached to mild steel centres; the cruising turbine nozzle plate is machined from a forging of stainless iron. The ahead and astern cylinders are cast from 0·5 per cent molybdenum steel. Pedestals, gland housings, bearing blocks, &c., are machined from plain carbon steel castings. The main fabricated casing and exhaust hood is made of mild steel plate.

Condenser.—A single-flow underslung condenser is incorporated in each main unit assembly. Reduction in weight and space has been achieved by adopting a circulating water velocity of 10ft per second; also by unit construction of the main turbine lower half casing and condenser shell, and by the acceptance of a vacuum of 23in Hg. at full power in tropical waters (cooling water temperature 85 deg. Fah.).

The cooling water inlet pipes and water boxes are designed to give a smooth uniform flow entering the tube plate and to minimise the possibility of erosion caused by turbulence, eddies and friction. The shell, together with its external ribs, internal gussets and washplates, is of welded construction, fabricated from steel plates and bars. The tube plates are of rolled naval brass. The tubes, ¾in outside diameter by 19 S.W.G., are of 70/30 cupro-nickel secured by Crane Wilkie cone type packings at the inlet ends and Crane full-box type packing at the return ends without use of ferrules. Two sagging plates are fitted between the tube plates.

Unrestricted flow of the steam over the entire length of the tubes is facilitated by the unit construction of turbine exhaust casing with the wide boat-shaped shell. Approximately 18 per cent of the tube surface is separated from the main bank of tubes by baffles of steel plate construction running the full length of the condenser and forms the air cooling section. The water boxes and end covers are combined and made of gunmetal.

In order to minimise losses due to throttling, both cruising and main turbines are each provided with four valves for the supply of steam to individual nozzle groups. The nozzle groups are designed to provide the following nominal power outputs:—

TABLE IX

Group numbers	Cruising turbine percentage of full power	Main turbine percentage of full power
1	5	30
1 and 2	10	45
1, 2 and 3	17	65
1, 2, 3 and 4	25	100

The nozzle control valves are entirely cam operated and are all of spherically seated Venturi type design for high steam velocity at the throat, with a diffuser exit, which serves as a velocity to pressure conversion tube. This design makes it possible to use a relatively small valve whilst maintaining a small pressure drop across the valve.

Operational Characteristics.—Speed is increased by turning the ahead hand wheel in the opening direction, which opens the four control valves sequentially until at approximately 25 per cent power all four are fully open. Until this point is reached the steam from the cruising turbine exhausts into the main turbine, by-passing the first four stages. Therefore all the power is produced jointly by the cruising turbine and the last four stages of the main turbine.

Further opening of the hand wheel rapidly closes the valves, simultaneously opening the first main turbine control valve, followed sequentially by the other three valves; thus at all powers above approximately 33 per cent all steam is admitted to the first-stage nozzles of the main turbine except for a small quantity admitted through the small pilot valve incor-

TABLE X

	Cruising turbine (clutch engaged)				Main turbine (cruising turbine declutched)			
Power, per cent	5·32	10·07	18·19	27·86	33	45	65·8	109
Power, s.h.p.	798	1,510	2,720	4,180	—	—	9,850	16,320
Steam pressure, lb per sq. in absolute	594	592	590	585	583	573	554	409
Steam temperature, deg. Fah.	827	827	827	827	827	827	827	827
Vacuum (bar. 30in) Hg.	27·41	26·88	27·34	26·78	26·59	26·0	25·15	23·0
Gear efficiency, per cent	92·5	92·95	93·3	94·3	—	—	95·94	96·7
Steam consumption, lb per s.h.p. hr	8·93	8·57	8·24	8·24	—	—	7·85	8·03

porated in No. 1 cruising turbine control valve. Between approximately 25 per cent and 33 per cent power steam is admitted simultaneously to the nozzles of both cruising and main turbine in order to produce a smooth change when transferring power from the cruising turbine to the main turbine and vice versa when decreasing power.

The clutch designed and manufactured by D. Napier and Son, Ltd., operates automatically; when increasing power it disengages as soon as the steam quantity to the cruising turbine is insufficient to maintain it when running at the synchronous speed of the main turbine.

When reducing power the clutch engages when the steam flow to the cruising turbine is sufficient to take it up to the synchronous speed of the main turbine and it will remain engaged so long as there is a power output from the cruising turbine.

Incorporated in the clutch is a device whereby the clutch can be withdrawn manually and held in the disengaged position. This action is effected by winding a hand wheel to the disengaged position, the first movement of which trips the cruising turbine emergency stop valve; this shuts off all steam to the cruising turbine and so prevents the overspeeding which would otherwise occur due to removal of the load following clutch disengagement.

The clutch is put into the manually withdrawn position when the ship is undergoing operations involving rapid manœuvring, also when steaming astern. In the event of any damage occurring to the cruising turbine, it can be disconnected, in which case the ship is capable of all operational requirements, power being obtained from the main turbine alone.

Summary of Shore Trials.—Table X shows the steam consumption over the power range examined during the shore trials at Pametrada. Fig. 6 shows the steam consumption over the full power range, the two missing points being

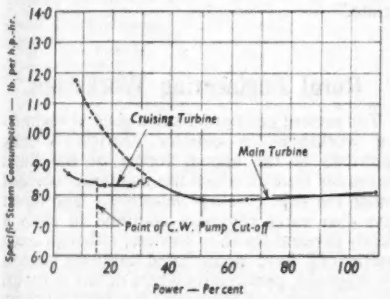


Fig. 6—Steam consumption in "Y.100"

estimations. The upper dotted line shows the steam consumption at cruising power when running with the cruising turbine disconnected.

Conclusions.—That the "Y.100" turbines fulfil the requirements of performance, particularly at very low partial powers, was adequately proved during the shore trials and sufficient experience has been obtained at sea to show that they satisfactorily perform the duties for which they were designed. There is little doubt that the difficulties which have been encountered relating to the clutch will be overcome by the modifications which are now being undertaken.

One aspect relating to the performance of "Y.100" is that the operation of the nozzle control valves combined with clutch engagement and disengagement is automatic, therefore the trial consumptions will be obtained in practice.

The requirement of lightweight machinery has been achieved, as shown by the following table of weights. A comparison of the "Y.100" machinery with that of the "Dido" Class cruisers, both of 15,000 s.h.p. per shaft, is shown, from which it can be seen that the reduction in weight is well in excess of the stipulated 33 per cent.

TABLE XI

	"Y.100"	"Dido" class
Turbines complete, tons	19·93	30·41
Gearing, tons	15·25	17·65
Condenser (wet), tons ...	6·97	17·43
Total...	42·15	65·49
Weight in lb per s.h.p. ...	6·3	9·77

Radio Aids for High-Speed Aircraft

The chairman's address to the Radio and Telecommunication Section of the Institution of Electrical Engineers was given by Dr. J. S. McPetrie in London on October 16. His subject was "Some Radio Aids for High-Speed Aircraft," with emphasis on the newer navigational aids, including the systems known as Tacan, Doppler, Dectra and others that depend on stable frequency oscillators. Abstracts from the address are reproduced below.*

HOWEVER adequate the communication between the ground controller and the pilot, the instructions to the latter cannot be satisfactorily carried out unless he already has a fairly precise knowledge of his position relative to the track which he is expected to follow. Any deviation from this track, in addition possibly to endangering the aircraft, will cause additional journey time, which is equivalent to a reduction in effective aircraft speed just as much as a delay at either end of the journey. The pilot must therefore have adequate navigation information at all stages of the flight.

There are a number of air navigation aids which have been in use for some time, such as D/F, Radio Compass, V.O.R., D.M.E., Gee, Loran, Decca and Console. As most of these have been described before, my remarks will be restricted to some of the newer radio-navigation aids which might be expected to come into general use in the next few years. Typical of these newer aids are Tacan, Doppler, Dectra and stable-frequency oscillators.

As its name implies, Tacan was developed originally for tactical use by single-seat fighters. The interpretation of the results obtained, therefore, had to be as easy as possible, any complexity being relegated to the design of the circuits in either ground or air equipment. Essentially, Tacan consists of a ground beacon operating in the 1000 Mc/s frequency band and energising a cylindrical aerial system rotating at a speed of 900 r.p.m. This aerial gives rise to a modulation in the signal received by any aircraft tuned to the beacon, and the phase of this modulation as measured in the aircraft is sufficient to determine the direction of the beacon from the aircraft. The ground beacon incorporates a transponder which can be triggered by the aircraft transmitter, the distance between the aircraft and beacon being given by the time between the initiating pulse from the aircraft transmitter and the reception of the signal in the aircraft from the beacon transponder. The duty cycle of the ground transmitter remains constant by ingeniously modulating it with noise pulses while no aircraft is interrogating the beacon and replacing the noise pulses by the interrogation pulses until the beacon becomes saturated with 100 simultaneous aircraft interrogations.

The bearing and distance of the interrogated beacon are both displayed in the pilot's cockpit on a single dial similar to that of a car speedometer, the directional information being given by a centrally mounted pointer and the distance by an inset counter. The range, as would be expected for a system operating in the 1000 Mc/s frequency band is limited to that of the optical horizon of the aircraft, with an overall limit of 200 miles. Aircraft speeds of up to 1500 m.p.h. can be accommodated. The Tacan system is not in general operation yet, there being only one ground beacon in the United Kingdom installed at Farnborough. However, there is every hope that before long its use will be fairly widespread, as it is the first navigational aid which gives directly both distance and bearing of an aircraft from a known ground position.

The Decca navigator has been extensively used for ship navigation and is becoming popular as an air navigation aid. Owing to errors arising from ionospheric propagation effects its range is restricted to some 300 miles. A modification of the system to operate at ranges of 1000 miles or more, and called Dectra, has recently been tested in a "Valiant" aircraft across the Atlantic. The results suggest that, in Dectra, we may have an extremely valuable navigation aid for aircraft on transoceanic routes. Briefly, the system consists of a master and slave station operating at a frequency in the region of 70 kc/s and located about 100 miles apart normal to, and at each end of, the route along which a series of tracks is required. The proposal is that Dectra and Decca should form an integrated system, some of the airborne equipment being common. On leaving an airfield the pilot would have all the facilities for accurate navigation using Decca. This would allow him to navigate his aircraft into the Dectra field system so as to take up the track which he was scheduled to follow. Each Dectra track, of course, corresponds to a given phase difference between the radiations from the nearer master and slave Dectra stations. Near mid-route the pilot would transfer to the appropriate track formed by the two Dectra stations at the terminal end of his journey. When he approaches these stations, he can then obtain more accurate fixes from the Decca chain covering his destination airfield.

It is proposed that range determination for Dectra should be given by comparing the phases of the radiation received in the aircraft from the master stations at each end of the system. It is envisaged that continuous reception from both ends of the route may not always be possible, and so a stable-frequency oscillator will be carried in the aircraft as a memory aid during periods of poor reception. At present, the only Dectra stations are located in Newfoundland. In spite of this limitation, however, the "Valiant" aircraft has made a number of successful flights between Newfoundland and the United Kingdom, in one of which the first land sighted was on breaking cloud over the home station at Boscombe Down.

Stable-Frequency Oscillators

Changes in relative phase between the radiation from a stable-frequency transmitter on the ground and the phase of a correspondingly stable oscillator in an aircraft at nominally the same frequency can be used directly to determine changes in radial distance between the ground transmitter and the aircraft. When associated with any system giving the direction of the aircraft relative to a known ground position, the pilot can use his stable oscillator to determine his actual position. Alternatively, if two stable-frequency ground transmitters are available, the distance of the aircraft from each transmitter can be determined and thus the position of the aircraft. This system has not been used to date because of the extremely high order of frequency stability which is required. This can be seen from the following table, which gives the distance error resulting from comparing two oscillators supposed to be on identical frequencies f, but actually being on slightly different frequencies f and $f+\delta f$.

$\frac{\delta f}{f}$	Error		
	10 min	30 min	1 hour
	km	km	km
10^{-7}	18	54	108
10^{-8}	1·8	5·4	10·8
10^{-9}	0·18	0·54	1·08

It will be noted that the frequencies must lie within 10^{-9} of one another to reduce the errors to the order of 1 km over a period of one hour. Since the error in range determination arising from a given error in frequency setting is proportional to time, the accuracy of the stable-

* Royal Aircraft Establishment, Farnborough.

frequency oscillator as a navigational device becomes correspondingly greater as the journey time itself decreases. We may expect, therefore, to see increasing use of such devices as aircraft speeds increase.

Research in both the United States and the United Kingdom is proceeding into methods for using the spectral lines of molecules such as ammonia and caesium for the control of stable-frequency oscillators. The accuracy of frequency setting for such oscillators should be adequate for this purpose. Their frequency has the unique advantage of showing no frequency drift, a characteristic of, for example, quartz oscillators.

Most navigation systems require both ground and air equipments. Self-contained navigation aids are now making their appearance, and one of the latest of these is Doppler navigation. In this system, a radar carried in the aircraft illuminates the ground by forward and rearward looking beams. The ground returns in the two cases are compared in frequency, and as the difference corresponds to twice the Doppler component, the velocity of the aircraft relative to the ground can be determined. In the equipment produced in this country, the airborne radar also feeds alternately beams to port and starboard. By this means the effect of drift can be taken into account.

One great advantage of the Doppler navigator is that, theoretically, it has no limit in range. However, for the longer ranges it is advisable to check and correct, if necessary, the system when the aircraft passes over recognisable ground features *en route*.

An aircraft is made to approach the destination airfield along a series of recognised routes. With increasing density of air traffic and, particularly, with increasing aircraft speeds, the air traffic controller requires correspondingly increased range on his ground radar. However, increasing the range of a ground surveillance radar also increases the amount of information in all directions as well as along the traffic lanes. It would be much better for the controller to have access to the information gathered by radars located at some distance along the traffic lanes as well as a more modest range radar close to the airport. Such an arrangement of remote radars brings in the problem of transferring the information gathered by them to the ground controller. There are various possibilities of achieving this objective; for example, the complete p.p.i. display could be transmitted by radar relay. However, this is much too inflexible and expensive and, at the same time, sends more information to the ground controller than he requires for air traffic control purposes.

Radar Transmission Over Telephone Lines

Some work has been carried out at the R.A.E. by Mr. Hinckley on the automatic processing and transmission of radar data over normal telephone lines. In this scheme, the "raw" data from a plan position search radar undergoes signal integration, thereby allowing automatic detection of target signals without appreciable loss in maximum range of detection.

In the R.A.E. equipment, the occurrence of an integrated target signal above a given threshold automatically causes the (R, θ) co-ordinates of the target to be measured in binary digital form. The appropriate (X, Y) co-ordinates are generated simultaneously and passed to a magnetic core store. While the rate of input information to this store depends on the azimuthal distribution of aircraft, the information contained in the store is extracted at a steady rate such that the content of the store, if full, is extracted over a period equal to the rotational period of the radar aerial. The store, as at present constructed, can accommodate twenty-two digits of information about each of 625 aircraft. With a typical rotational period for the radar of ten seconds, the rate of transfer of information from such a store is 1375 bits per second, a rate which can easily be accommodated by a normal telephone line.

All the relevant air traffic control information at the distant radar can, by this means, be transferred automatically over a normal telephone line to the ground controller. As the information is already in Cartesian co-ordinates, allowance for the displacement of the remote radar can readily be made, so that, if necessary, the remote targets could be displayed directly on the plan position indicator already in use by the ground controller, or in any other way.

The conventional p.p.i. display of a radar at the R.A.E. has been compared with the corresponding decoded display after integration, automatic detection, conversion from polar to Cartesian co-ordinates, digital encoding, storage, with subsequent transmission over 150 miles of normal Post Office telephone circuit which passed through six public exchanges, and final decoding and display. In spite of the complex radar processing involved, little information was lost; in fact, the processed display is better than the original because in the processing certain irrelevant information is automatically suppressed.

It is believed that some such method for the automatic processing and transmission of radar information will be essential in the near future at all major civil airports in order to accommodate the increase in traffic density and aircraft speed which is to be expected.

Incidentally, a subsidiary, but very useful, advantage of the radar processing scheme is that, as the information can be carried adequately by a normal telephone circuit, it can equally well be transferred to a magnetic tape or similar recording. A p.p.i. display, in fact, has been made at the R.A.E. from a normal magnetic tape carrying processed radar data. Such a recording could be made of each aircraft approach to, and landing at, an airfield, when information would be available for any subsequent accident inquiry.

Looking further into the future, we can envisage a time, not so far distant, when the processed radar data can be used in a ground-based digital computer and appropriate command signals sent automatically to the aircraft controls so that a fully automatic approach and landing would be possible.

"Narrowly Vocational"

The City and Guilds of London Institute has printed the following comments in the October issue of its *Broadsheet*:

"Among the educational terms of abuse, 'narrowly vocational' has had a longer career than most. In particular, it is levelled against the technical colleges by many who have no real conception of the nature of their work or of the difficulties which for many years have faced them.

"To-day, most industries are very conscious of the need to foster the mental development and manual skill of their workers, and part-time day attendance at technical colleges is customary—except in a few indutries whose future will become increasingly doubtful if they fail to realise the needs of the present day. With more time available and better facilities for teaching, colleges have a chance to prove that the study of the fundamental principles on which an industry is based can be as valuable a mental discipline as any other. Work is an inescapable part of our lives and is potentially as interesting and as satisfying an experience as any artificial entertainment. The man or woman who knows *why* his or her job is done in the way it is has far greater opportunities for personal satisfaction than the worker who sees merely a few meaningless operations. Few people in a mechanised world have jobs in which they individually create something, but more and more are able, by virtue of technical education, to see how their own specialised efforts form part of a whole complex industrial organism. In this sense, any course, however humble its academic level, which supplements day to day working experience, has the effect of broadening the mind, so that to dismiss it as 'narrowly vocational' reveals a somewhat superficial view.

"This may appear to discount the value of the traditional 'non-vocational' subjects and to imply that there is no room for them in the technical college. Nothing would be further from the truth. More part-time day work implies that more people are looking to the technical college for genuine further education, and the growing size and complexity of all forms of social organisation bring home forcibly the need for skilled guidance in how to live in modern society. The publication of the Ministry of Education circular (No. 323) on ways of broadening courses in technical colleges, is a timely recognition of the fact that 'vocational' and 'non-vocational' (always an artificial distinction) have become so intermingled that the study of man in an industrial environment is essential for all who will be concerned with running the industry of the future.

"Before the publication of the Ministry of Education circular, the Institute was already at work on a new course in mechanical engineering craft practice, which includes social studies as an essential part of the syllabuses. This represents the first comprehensive national attempt to ensure that the ordinary craftsman has the opportunity of seeing his work in its wider setting. During the four years of the course he will appreciate the importance in the adult world of the correct use of English, the logical expression of ideas, and how to use the resources of libraries to best advantage. Through the history of his own industry and of his locality he will begin to understand the complex evolution of British society and the way in which national and local government operates. Comparative study of the forces which express and mould public opinion, such as the press, radio, television and films, will help to explain many aspects of ordinary life and behaviour, and will associate logically with thoughts on the use of leisure time.

"The Institute has made this beginning in an appropriately experimental way. The social studies will not initially form the subject of an examination externally set by the Institute. Colleges will have the maximum freedom to deal with the topics in whatever way best suits the needs and resources of the locality; the Institute will ask only for evidence that the social studies have been tackled as an integral part of the course and have been examined by the College. The problems of presenting the subjects to craft students in a realistic and palatable way are challenging and will give colleges real opportunities to break new ground. The Institute, for its part, will look at other courses to see how far developments comparable with the mechanical engineering craft practice course are appropriate."

Rural Engineering Workshops

The present position of small general engineering workshops in country districts is aptly described in the annual report of the Rural Industries Bureau, which has just been published under the title *Country Industries*. The report says that rural engineers continue to enjoy a steady demand for their services, although credit restrictions have necessitated cautious business management, particularly where outlay of capital for new plant and equipment has been involved. Those who have kept abreast of modern developments, however, have generally found no shortage of work. But, the report points out, the rural workshop which, in the past relied on the forge and anvil, is no longer capable of providing an adequate service to modern farm machinery.

One of the many activities of the Rural Industries Bureau is to advise rural engineers on the choice and suitability of tools and equipment for servicing farm machinery, and to teach new skills by individual or group instruction. Thus, in many cases, the report records, the blacksmith's shop has developed into an up-to-date engineering repair shop. Many rural engineers are seeking to build new workshops to replace unsuitable and poorly lighted premises, and the Bureau's engineering staff spends a great deal of its time surveying sites, interviewing authorities and preparing plans for workshop buildings. Nevertheless, records of visits made last year show that, among the technical services offered by the Bureau s engineering section, instruction in manual techniques is still most in demand. Individual training is provided by the Bureau's engineering instructors in gas and arc welding, basic smithing, centre lathe turning, and bench fitting.

The report includes, of course, accounts of the Bureau's work for other rural industries. A foreword by Sir Basil Mayhew, chairman of the trustees, fittingly says that the "Bureau's service has been entirely of a practical nature; the average country craftsman is unreceptive to any advice and any help offered to him must not only be sound, but preferably demonstrable."

International Motor Show

No. II—(*Continued from page 565, October 18*)

IN our report last week we dealt with the latest models of the medium-sized cars, made in large-scale production by the five big concerns which between them account for almost 90 per cent of this country's production. We have already mentioned that in this particular field the design has remained static and, with the main emphasis nowadays placed on styling, minor changes only are apparent in the general layout of the mechanical units. However, our table shows that variation in detail design survives. Examples of the more advanced school of automobile engineering are almost entirely confined to those British cars which are made in small quantities. Here the design is generally more flexible than that of mass-produced cars, and we find, especially among fast sports cars, a number of constructional details which—though probably not particularly suitable for quantity production—are worth studying.

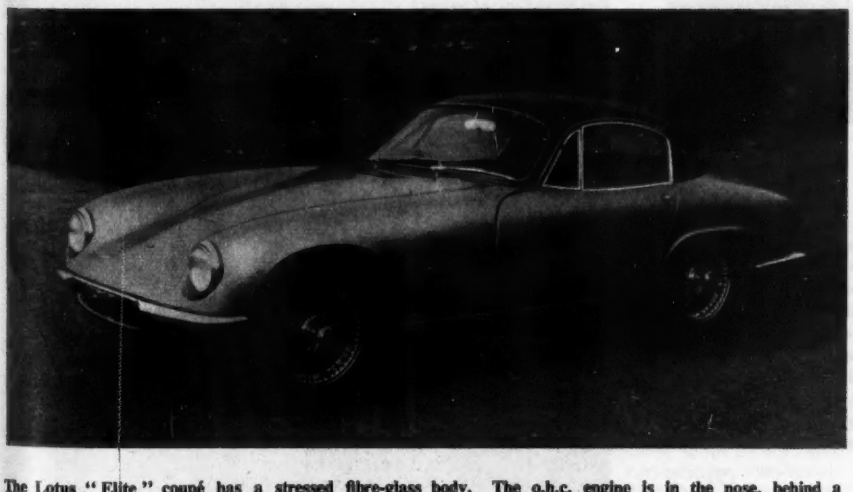
Cars with Double Wishbone Front Suspension, Hotchkiss Drive, Manual Transmission and In-Line-Valve Push-Rod Engines. In all cases the engines are Carburetted, Water-Cooled, Single-Bank Units

Feature	Austin "Metropolitan"	Austin "A.35"	Austin "A.55"	Austin "A.95"	Austin "A.105"	Austin "Princess"	Austin-Healey	Morris "Minor"	Morris "Cowley"	Morris "Oxford"	Morris "Isis"	M.G. "Magnette"	M.G. "M.G.A."	Riley "2·6"	Wolseley "1500"	Wolseley "Fifteen-Fifty"	Wolseley "Six-Ninety"	Daimler "One-o-Four"	Daimler "D.K.400"	Hillman "Minx"	Humber "Hawk"	Sunbeam "Rapier"	Standard "Eight," "Ten," "Pennant"	Standard "Ensign"	Standard "Vanguard," "Sportsman"	Triumph "T.R.3"	Vauxhall "Cresta"	Vauxhall "Velox"	Vauxhall "Victor"
Fully floating driven axle																									★		★	★	★
Synchromesh on all forward gears																													
Independent hydraulic systems for front and rear brakes																													
Provision for hand cranking engine		★	★	★	★			★	★	★	★	★	★	★	★			★	★	★	★	★	★	★	★	★			
Provision for hand priming fuel pump or stand-by electric pump	★	★	★	★	★	★			★	★	★	★	★	★	★			★	★	★	★	★	★	★	★	★			
Reserve fuel supply																		★	★										
Separate fuel filter/water trap				★	★	★	★		★	★	★	★	★	★	★	★	★	★	★			★	★	★	★	★	★	★	★
Oil pressure gauge				★	★	★	★		★	★	★	★	★	★	★	★	★	★	★	★	★	★			★	★	★	★	★
Water temperature gauge																													
Ammeter					★	★	★		★	★	★	★	★	★	★	★	★	★	★	★	★	★			★	★	★	★	★
Engine r.p.m. indicator																													
Windscreen washer					★	★	★				★	★	★	★				★	★	★	★	★	★	★	★	★	★	★	★
Self-parking wipers																													
Laminated windscreen																													
Separately switched "ignition" and "services" circuits	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★
Underbody protection by resilient sealing coat																													
External fittings stainless steel or aluminium																				★	★						★	★	★
Unified threads throughout	★	★	★	★	★	★	★											★	★	★	★	★					★	★	★
British Standard threads throughout																							★						
Optional or additional :																													
Two pedal control			★							★		★				★				★			★						
Automatic transmission				★	★		★				★			★			★	★			★								

Model identification

A car of modern conception is the "Elite" two-seater coupé of Lotus Engineering Company, Ltd., a competition model designed for a top speed of 130 m.p.h. In contrast to the open sports cars of the firm which have a multi-tubular frame structure with aluminium panelling, the coupé has no chassis in the accepted sense, but the main assembly consists of a stressed body structure built up from polyester glass mouldings, combining tensile strength with adequate impact resistance. The principal components consist of a large front moulding, a combined roof and rear moulding, and an undertray which also comprises the propeller shaft tunnel. Other plastic components include the doors, the bonnet cover and the boot lid. Metal straps are used to reinforce the body structure at the heavily stressed parts, for instance at the attachment points for the engine mountings and the suspension. Epoxide resin adhesives are used to bond metal and metal or metal and plastics, thus avoiding the need for riveting.

The layout of the transmission and the brakes is similar to that of the 1100 c.c. Lotus "Le Mans" sports car, described on the occasion of last year's show in THE ENGINEER of October 19, 1956. The De-Dion rear axle, however, has been replaced by an independent suspension incorporating combined coil-spring damper units, pivoted high inside the body structure, which act in the manner of a MacPherson front suspension, and parallel trailing arms. The engine is the latest 1·22-litre Coventry Climax o.h.c. four-cylinder engine, of 76mm bore and 66·6mm stroke, which, at a compression ratio of 10 : 1, develops 90 h.p. at 6800 r.p.m. Its design is basically the same as that of the sufficiently well-known 1·1-litre engine. The Lotus "Elite" coupé has a wheel base of 7ft 4in, a track of 3ft 11in, is 12ft long, less than 4ft high, and weighs only 10½ cwt.



The Lotus "Elite" coupé has a stressed fibre-glass body. The o.h.c. engine is in the nose, behind a rearwardly-inclined radiator, and drives the independently sprung rear wheels

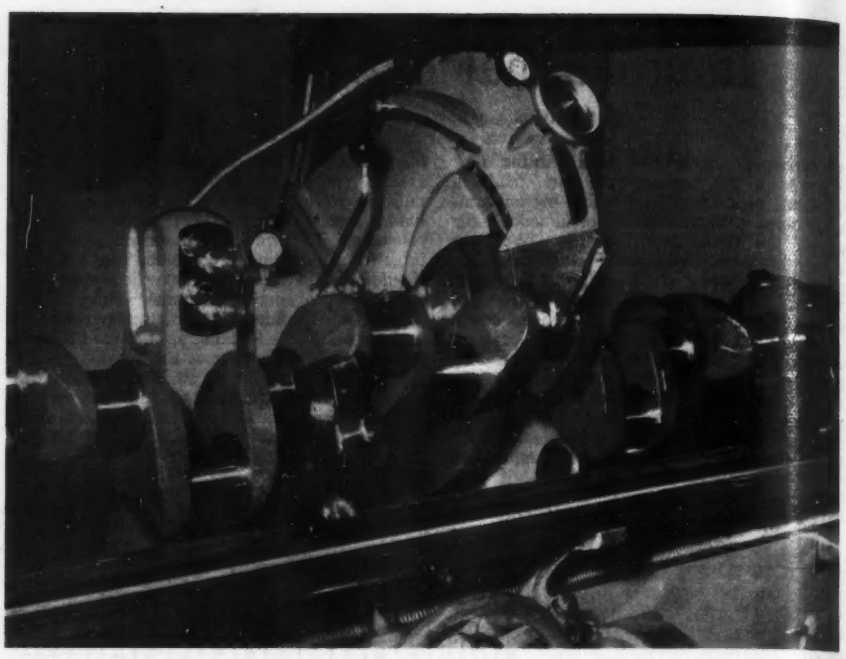
Three light cars with tubular chassis and plastic bodies are exhibited by Fairthorpe, Ltd., a firm displaying its products for the first time at an Earls Court show. The three models use proprietary main components and are of entirely conventional design, apart from the rear suspension, which employs a live rear axle in conjunction with coil springs and trailing wishbones. The "Electron" coupé is fitted with a 1·1-litre Climax engine, the "Electron Minor," with a 1-litre "Standard Ten" engine and gearbox, and the "Atomota," also an open two-seater sports car, with an air-cooled, 650 c.c. B.S.A. motor-cycle engine and a Standard "Ten" gearbox. The latter car has a dry weight of less than 10 cwt.

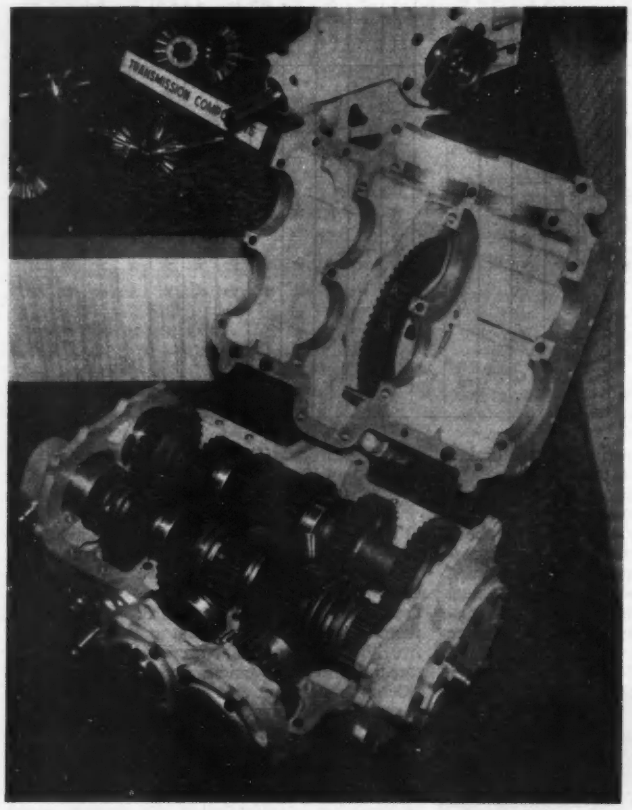
Miniature Cars

Turning now to the so-called "miniature" cars, i.e. to small vehicles with engines from about 250–600 c.c. cylinder capacity, we notice that in this group two British firms are represented at the show as against six foreign firms. Although there have been rumours that at least one of the five big motor manufacturers has been experimenting with such vehicles and actually was considering marketing an entirely new "economy" car, this rather hypothetical intention seems to have been abandoned or temporarily shelved. The industry on the whole is by no means convinced that there is a sufficiently large demand for this type and, while realising that cheaper cars would be desirable, believes that public opinion would be opposed to a car which, in appearance as well as in its overall technical conception, does not conform to the old-established idea of "what a car ought to look like." It must appear that British constructors see little opportunity of entering the market for small economy cars, nor do they see at present any great future for such vehicles in overseas countries. The cautious attitude of the industry seems reasonable; public taste and public reaction are difficult to foretell, and it is doubtful whether a small car, unless inexpensive and of pleasant appearance, will catch on in this country. Such a car, in order to be sufficiently attractive, had to be made by some big manufacturer and produced in large-scale production, requiring a considerable capital investment. Aggravating circumstances are that few British manufacturers are familiar with the constructional pre-suppositions of miniature car

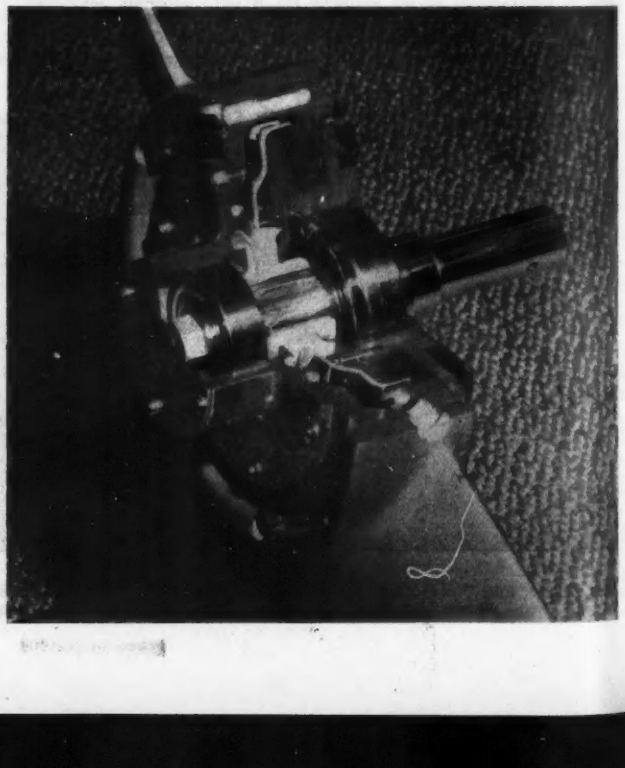
Equipment and Components

A new crankshaft regrinding machine shown by Prince (Kingston) Engineers, Ltd., has the ability of the smaller machines to grind both main and crankpin journals at one concentric setting up, and in addition also incorporates provision for correction or alteration of stroke. The main journals are centre ground, but the pins are ground centrelessly, as can be seen in the illustration. The rider attached to the wheelhead is, of course, less than perfectly rigid and the actual metal removal depends upon the force with which the wheel-head leans upon it. By rendering the wheelhead heavily unbalanced, metal removal can be concentrated on either the outside or inside arc of the pin ; normally wear will be heaviest on the inside and the stroke will be restored to original. An indicator showing the change in stroke achieved can be seen above the work ; a stroke measuring device which mounts upon the rails in front of the bed of the machine is being developed. Strokes up to 8in and shafts up to 80in long can be handled.





This five-speed final drive is designed for the Aston Martin racing sports cars with dead rear axles : compactness was of first concern, and led to the use of straight-toothed gears to avoid generating end thrusts. The only helical train is the initial input and the end thrust on the driven gear is opposed by the thrust on the input bevel. All the forward trains will stand full engine torque and all except first are provided with oil sprays on to the teeth, each spray being supplied through the hollow selector rod and starting only when the gear is engaged. Engagement is by dog clutches, the dogs being inverse tapered to avoid any tendency to disengage under load : dogs on each member are alternately long and short in the axial direction, so that synchronisation need not be more exact than if clutches allowing a great deal of radial play were used. The shift pattern brings reverse opposite fifth, any other arrangement requiring a larger casing. The output gear can be changed to provide coarse alterations of ratio, five gears with from fifty-eight to seventy-eight teeth being used, and different packing pieces under the differential casing effect the necessary variation in centre distance ; fine variations require the two input gears to be changed. Third gear is very close to 1 : 1, the lower gears being spaced about 1·45 and the higher gears progressively closer ; tooth numbers total fifty-nine or sixty, the variation being allowed for by connecting up varying amounts. Dry sump lubrication with an extreme pressure oil, Hypoid 90, is used on this car : a strainer protects the scavenge pump. The pressure pump is on the end of the main shaft and keeps its hollow centre pressurised to feed the bearings. The box will accept 250ft-lb up to 4000 r.p.m. (190 h.p.) and 6500 r.p.m. : high speed bearings are used, and no bearing has yet been replaced. The boxes are stripped and examined after every race, but so far no defect has occurred within the actual box. In the background can be seen a final drive for a de Dion sports car.

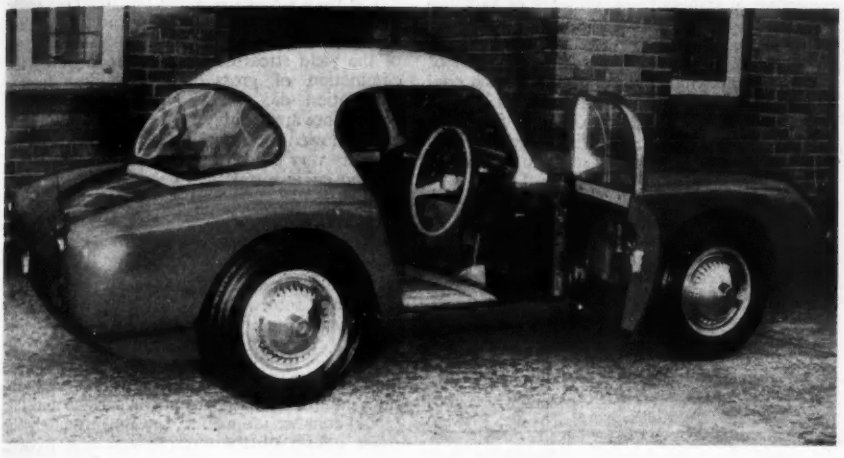


The Smiths electromagnetic clutch is seen here applied to a cooling fan. The fan is cast in light alloy and the clutch built into its hub. It can be inferred that the very rapid response of such a device, compared to, say, a movable blind, would simplify the provision of an automatic control of coolant temperature.

design, such as air-cooled engines, independent rear suspensions, rear-engine mounting and front-wheel drive. It would need a prolonged period of extensive experimental work until a design could emerge, good enough to compete with those of Continental manufacturers who have already been working in this particular field for several years.

The present domestic demand for miniature cars can easily be satisfied by motor-cycle factories or by firms which make no attempt to compete with large-scale production, but are content to satisfy a limited demand without any excessive financial engagements. Whether or not such firms, few of which have large resources or an adequate sales and service organisation, will be able to expand their export sales against an already well-established Continental competition remains to be seen.

The first British miniature car ever seen at the Earls Court motor show was the "Berkeley" front-wheel drive sports two-seater, shown as a prototype at last year's exhibition. This attractive little car, the design of which embodied sound engineering principles, was described in THE ENGINEER of October 19, 1956. In the last twelve months it has been built at the rate of about 100 units per month and, within limits, has become popular. This year two more models of this car are being displayed at the stand of Berkeley Cars, Ltd., a *de-luxe* version of the standard type and a hard-top coupé with a more powerful engine. The standard version remains basically unchanged, but the former air-cooled, twin-cylinder, 322 c.c. British Anzani two-stroke engine has been replaced by a 328 c.c. Excelsior engine of similar construction. The new engine, of 58mm bore and 62mm stroke, has an output of 18 h.p. at 3000 r.p.m., and can be fitted either with one or with two carburetters. The coupé is equipped with the three-cylinder, 492 c.c., version of the same engine, which, fitted with three carburetters, develops 30 h.p. at 5500 r.p.m. Both body and underframe of the Berkeley models are made of resin-bonded moulded glass fibre with aluminium bulkheads and cross members. All wheels are independently sprung, and the torque from the transversely mounted engine is transmitted via a primary chain to the gearbox (with three forward ratios for the two-cylinder and four for the three-cylinder engine), and through a secondary open chain to the differential which drives the front wheels. The standard model has a wheelbase of 5ft 10in, a track of 3ft 8in, and weighs dry about 6 cwt.



The "Berkeley" has lost its former light and simple wheel mountings. The gear selector has been transferred to the otherwise unobstructed floor, but remains progressive

The rear-engined "Frisky," made by Henry Meadows, Ltd., is shown in two forms, a saloon seating two adults and two small children, and a sports model with room for three adults. Since its first appearance as a prototype at this year's Geneva show the body style has been modified, and the original gull-wing doors replaced by orthodox doors. The basis of the "Frisky" is a tubular chassis which carries the plastic fibre-glass body. The front suspension is of the Dubonnet type with rubber in tension as the springing medium, both suspension units pivoting about the stationary kingpins. Spring-loaded friction discs, attached to the wheel arm and the casing of the rubber bush respectively, act as dampers. At the rear, telescopic coil-spring damper units pivoted on brackets attached to the upswept side members, locate the solid rear axle in conjunction with two trailing arms. The car is powered by a fan-cooled 325 c.c., twin-cylinder Villiers two-stroke engine, developing 16 h.p. at 5500 r.p.m., which, together with the integral four-speed gearbox, is mounted transversely at the rear of the car. There is primary chain drive to the four-speed gearbox; the final drive to the rear axle is effected by a secondary fully encased chain; a rubber bellows in the split chain case permits freedom of axle movement. The rear sprocket is bolted to a flange welded to the axle tube, the latter being carried in two ball bearings which are housed at the bottom ends of the coil-spring damper suspension units. As the rear track is only 2ft 8in wide (compared to the 4ft wide front track) no differential is considered necessary.

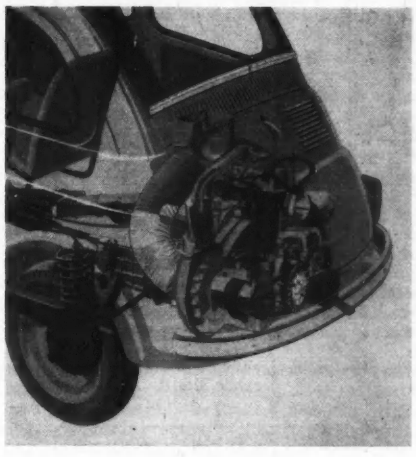
The Berkeley as well as the "Frisky" deviate from orthodox British practice in as far as each construction employs one of the two drive arrangements (front-wheel drive or rear-engine mounting), which, according to the Continental school of automobile engineering, are the most suitable systems to provide the best space utilisation and the maximum riding comfort in cars with less than 90in wheelbase. Both cars, with their plastic bodies, are not designed to be made in large production; the necessity of using standard proprietary units for the main mechanical components has obviously limited the designer's scope.

When comparing the British miniature cars with equivalent Continental designs, it will be noted that most of these latter vehicles are either made by big automobile factories like Fiat and Citroen, or, in Germany, by motor-cycle manufacturers using as far as possible suitably modified components of their own production. As a rule, the Continental miniature cars are actually designed to be made in large-scale production, and the designer, not compelled to buy the main components from outside firms, has more freedom of action than his opposite number in this country to adapt and modify these units according to his layout. However, in spite of these obvious advantages which are bound to have a favourable effect on the overall design, the latest examples of Continental mass-produced miniature cars are not showing any noticeable progress when compared with some of the older constructions, as, for instance, with the 2 c.v. Citroen, the 750 c.c. rear-engined Renault and with the Fiat "600," all of which have remained practically unchanged. In most of the new cars the engine capacity has been raised to more than 500 c.c., giving an output of about 20 h.p., and the formerly popular two-cylinder, two-stroke engine has been replaced by some high-performance, fan-cooled, four-stroke engine. Whether or not the now fashionable vertical twin four-stroke, with its considerable unbalanced inertia forces, will be the final solution remains to be seen, and many experts expect the revival of the better balanced horizontally opposed, two-cylinder, four-stroke engine.

Most of the German small cars displayed at the show have been known in this country for some time or have been described in our recent article on the Frankfurt motor show. An interesting example of advanced automobile engineering is the Italian Fiat "500," an entirely new car, developed over a number of years and first marketed early this year after extensive road testing. It makes its first public appearance in this country at the stand of Fiat (England), Ltd., and is attracting a great deal of attention.

The new Fiat, in appearance, is basically a scaled-down version of the established rear-engined Fiat "600"; it also resembles the latter in most of its technical features, but, instead of the water-cooled, four-cylinder engine of the type "600," it has a fan-cooled, vertical, twin-cylinder engine longitudinally mounted at the rear of the car.

The Fiat "500" is built in integral construction and has a roll-back sunshine roof; there are two individual front seats, with a luggage platform behind them which could carry two children. The general conception of the car, its body structure, and such constructional details as the independent all-wheel suspension and the layout of the transmission, closely follow the well-known principles of the bigger type. The air-cooled 480 c.c. two-cylinder o.h.v. engine of 66mm bore and 70mm stroke has a compression ratio of 6·55 : 1, and develops 13 h.p. (net) at 4000 r.p.m. The separate cast iron cylinders have aluminium cylinder heads and are mounted on a tunnel-type, two-bearing light metal crankcase. The thermostatically controlled cooling air is delivered to the cowled cylinders from a large radial fan, arranged at the left-hand side of the engine, and driven together with the 12V dynamo by a vee belt. The complete engine-transmission unit is resiliently mounted, the rear end being supported by a large coil spring. The torque is transmitted via a dry single-plate clutch to the constant-mesh four-speed gearbox and then, in the usual way, through the final drive and the universally jointed half-shafts to the rear wheels. The car has a wheelbase of 6ft 0½in, a mean track of 3ft 8½in, and an overall length of 9ft 9in; its kerb weight is 9½ cwt. Being about 9in shorter than the type "600," the floor space is naturally somewhat restricted, but it offers reasonable seating comfort for people of normal size. Road-holding and springing are quite good for a car of such short wheelbase, but the noise of the air-cooled engine, though reduced by reason of the soft fabric roof, causes a certain amount of displeasure.



The vertical twin engine of the Fiat "500" can be seen in this drawing

(*To be continued*)

Metallurgical Topics

Low-Temperature Properties of High-Purity Iron

ALPHA-IRON has a body-centred cubic structure. In general, metals which have a body-centred cubic lattice become brittle at low temperatures, whereas face-centred cubic metals remain ductile. It may be that traces of impurities decrease the low-temperature ductility of the body-centred cubic lattice, and that in the absence of such impurities the body-centred cubic lattice might exhibit nearly the same ductility as the face-centred lattice at low temperatures. In order to investigate this possibility, R. L. Smith and J. L. Rutherford* have measured the low-temperature tensile properties of high-purity iron in which the impurities have been still further reduced by the zone refining process.

Zone refining is brought about by traversing a relatively long charge of solid metal by a small molten zone. It is distinct from normal directional freezing in that the operation may be repeated until segregation is almost eliminated over the greater part of the charge. It thus affords a means of purifying the solvent metal. The principles of zone melting were discussed by W. G. Pfann.† The process is usually carried out on material lying in a horizontal container, but Smith and Rutherford have adopted a modified procedure known as the floating zone method.‡ In a rod of metal held vertically a narrow molten zone is formed by induction heating. The molten zone is supported between the two solid sections of the rod by surface tension. It is then moved longitudinally along the rod in order to effect a redistribution of the solute. This technique has an advantage over the longitudinal boat method since crucible contamination is avoided, but it is much more difficult than the more usual method of zone melting.

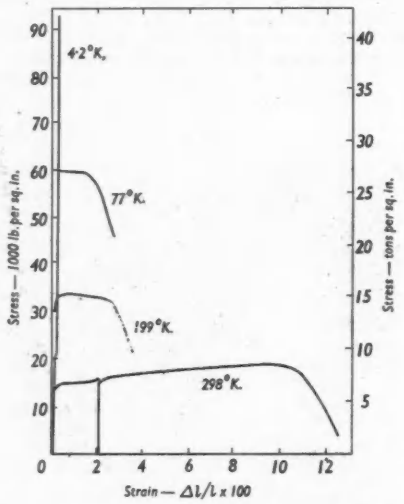


Fig. 1—Tensile properties of vacuum-melted iron, grain size 8

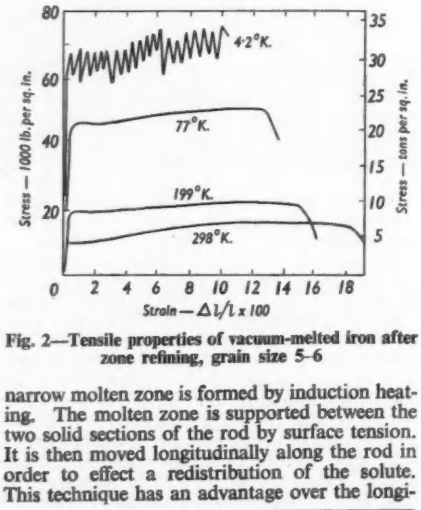


Fig. 2—Tensile properties of vacuum-melted iron after zone refining, grain size 5–6

Rods of vacuum-melted and arc-melted iron of high purity were used as starting materials. After zone purification in dry hydrogen the rods were swaged to 0·0625in diameter, annealed in a vacuum at 900 deg. Cent., then drawn to 0·031in diameter and cut to specimens of ¾in gauge length. The specimens received a recrystallisation treatment at about 600 deg. Cent. and were tested in a specially constructed loading apparatus.

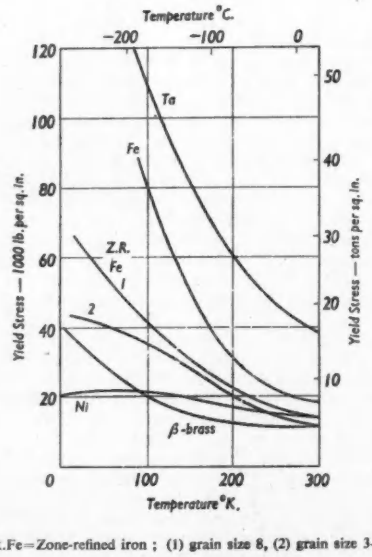
It was found that the higher the purity of the iron the lower were the flow stresses and the better the low-temperature ductility as measured by elongation. Yield stresses as low as 1·7 tons per square inch were observed at room temperature and elongations up to 10 per cent at 4·2 deg. K. (−269 deg. Cent.). Some results are illustrated by Figs. 1 and 2, showing the tensile properties at different temperatures of vacuum-melted iron and of the same material after zone purification. The elongation of the vacuum-melted iron at 4·2 deg. K. was of the order of 0·5 per cent, while that of the same material after zone refining was about 10 per cent. Other relevant figures, read approximately from the curves in the paper, are given in Table I. Table II shows the ratio of ultimate stress to yield stress for the different materials at different temperatures, the diminishing ratio indicating that there is a decrease in strain hardening with decreasing temperature from room temperature down to 77 deg. K., whereas from 77 deg. to 4·2 deg. K. the ratio increases. The ratio is 1 when the load continuously decreases from the upper yield point, and maximum load and yield point are the same. The tensile curves of the zone refined iron at 4·2 deg. K. showed sharp serrations which may be attributed to a mixture of deformation by slip and by twinning. Twinning occurred throughout the tests at 4·2 deg. K. and it was not restricted to the immediate vicinity of the fracture. Twinning which occurred at higher temperatures could be inhibited by prestraining at room temperature, but this treatment did not suppress twinning at 4·2 deg. K. Its primary effect at that temperature was to increase the stress necessary to produce twinning.

TABLE I—*Ductility in Tensile Tests of Arc-Melted Iron Before and After Zone Refining*

Temperature		Uniform strain, per cent		Reduction of area, per cent	
Deg. K.	Deg. Cent.	Before	After	Before	After
4·2	−269	0	5	0	15
77	−196	10	11	25	40
199	−74	12	13	80	75
298	25	10	18	90	90

TABLE II—*Ratio of Ultimate Stress to Yield Stress of Iron Before and After Zone Refining*

Temperature		Vacuum melted iron		Arc-melted iron	
Deg. K.	Deg. Cent.	Before	After	Before	After
4·2	−269	—	1·20	—	1·23
77	−196	1·0	1·07	1·06	1·11
199	−74	1·02	1·11	1·24	1·29
298	25	1·32	1·74	1·60	1·61



Z.R.Fe=Zone-refined iron ; (1) grain size 8, (2) grain size 3–5.

Fig. 3—Effect of low temperatures on the yield stress of various metals

The yield stresses of some body-centred cubic materials, viz. tantalum, α-iron and β-brass, are shown in Fig. 3. The temperature dependence of the yield stress of iron was reduced by the elimination of gross impurities, but further purification did not change the temperature dependence appreciably. The purest iron investigated showed a curve of yield stress against temperature very different from that typical of face-centred cubic metals as illustrated by the curve for nickel.

Residual Grinding Stresses

MOST machining operations induce some kind of residual stress at or near the finished surface. These are sometimes of no consequence ; at other times they may be harmful. Grinding is especially likely to induce residual stress, the more so as it is frequently applied to very hard materials. Some grinding conditions may produce compressive stresses at the surface and this would enhance fatigue life, but unfortunately the exact nature of the stresses resulting from a particular grinding operation is usually unknown. If the correct conditions are not met fatigue life may be reduced. This being so, a stress-free surface is the safe alternative and to attain this an effective routine method is needed for reducing residual stresses after the final grinding operation without affecting the normal properties of the metal adversely.

Experiments have been described by H. R. Letner and A. B. Sauvageot,* in which identically ground tool steel specimens were reheated and the effects upon residual stress and hardness measured. The steel used contained carbon 0·90, manganese 1·25, tungsten 0·5 and chromium 0·5 per cent. It was in the form of 2in by 0·25in bar. The bar was cut into 2in lengths and the top and bottom surfaces were ground to bring the thickness to 0·20in. These square specimens were quenched from 1450 deg. Fah. (788 deg. Cent.) in agitated oil at 70 deg. Fah. Their hardness was then Rockwell C 64. Half the specimens were tempered for one hour in a fused nitrate bath at 420 deg. Fah. (215 deg. Cent.) and cooled in air, after which their hardness was Rockwell C 59. The specimens were then ground in a surface grinder, ten down-feeds of 0·001in being removed. The residual stresses were ascertained by the deflection technique, in which a thin layer is etched from the surface and the change in curvature resulting from the release of the force exerted by the removed layer is measured. The principal stresses σ_1 parallel to, and σ_2 at right angles to the path of the abrasive along the surface were calculated. In a typical tempered specimen σ_1 (max.) was about 62,000 lb per square inch and σ_2 (max.) about 19,000 lb or 20,000 lb per square inch. A stress-relieving treatment was applied by heating the specimens at different temperatures and for predetermined times in a nitrate bath with automatic temperature control, and cooling them in air, oil or water. After various exploratory experiments with the quenched material,

* *Journal of Metals*, July, 1957, page 857.
† *Journal of Metals*, July, 1952, page 747.
‡ *Journal of Metals*, April, 1957, page 478.

* *Metal Progress*, September, 1957, page 79.

attention was concentrated on the tempered specimens of hardness Rockwell C 59. The steel in any case would not normally be used in the untempered condition. Neither stress nor hardness was affected by heating at 420 deg. Fah. for five minutes and cooling in air. A similar treatment at 600 deg. Fah. for five minutes lowered σ_1 (max.) to 17,000lb and σ_2 (max.) to 6000 lb per square inch, but the hardness was reduced three points on the Rockwell scale. Treatment at 600 deg. Fah. for ninety seconds followed by quenching in water reduced the peak stress σ_1 to 20,000 lb and σ_2 to less than half its original value (as shown in Fig. 1), while the hardness was

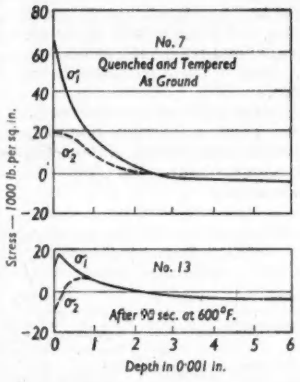


Fig. 1—Principal internal stresses in a tool steel specimen (2in by 2in by 0·2in) quenched and tempered to a hardness of C 59 and surface ground; and residual stresses in a similar ground specimen of hardness C 59 after ninety seconds at 600 deg. Fah., followed by cooling in water

reduced only about half a point on the C scale. When this treatment was followed by cooling in oil or in air, relief of stress was the same but the hardness was reduced by one to one and a half points. Some results of the ninety-second treatments are given in Table I. The method of

TABLE I—*Effect of Reheating Ground Specimens of Hardness Rockwell C 59 (740 V.P.N.) for Ninety Seconds and Cooling them in Water at 80 Deg. Fah.*

Specimen No.	Temperature,		Internal stresses 1000 lb per square inch		Softening
	Deg. Fah.	Deg. Cent.	σ_1 max.	σ_2 max.	
7	As ground		62	19	—
14	500	260	36	20	None
15	550	288	30	9	None
13	600	315	20	8	0·6 point
16	650	343	10	6	2·3 points

Hardness determinations were said to be correct to ±1 point in the Rockwell C scale (±24 V.P.N. at this part of the scale).

cooling had little bearing on the amount of stress relief, but softening was less when the specimen was rapidly cooled. The treatments not only reduced the peak tensile stresses but also relieved stresses at all depths. As is indicated in Fig. 1, the transverse stress was also favourably affected, the original tensile stress being converted into compression near the surface.

In practice steel of larger section than the specimens is used, but to relieve grinding stresses it is only necessary to heat the surface, and it was shown that with sections of 2in diameter the surface reached or closely approximated to the temperature of the bath in ninety seconds, provided that the steel was moved about in it.

The recommended procedure was therefore to immerse the piece in a salt bath between 500 deg. and 600 deg. Fah. (260 deg. and 315 deg. Cent.) for ninety seconds and then cool it in water or agitated oil. In the range 500 deg. to 600 deg. Fah. from 40 to 65 per cent reduction in grinding stresses could be expected. The temperature should not appreciably exceed 600 deg. Fah. if softening by more than one point is to be avoided. If a small decrease in hardness could be tolerated the temperature might be raised to 650 deg. Fah. (343 deg. Cent.), which would reduce the peak grinding stresses by about 80 per cent.

Fatigue Tests on Alpha-Iron

THE influence of orientation on the fatigue strength of α-iron has been investigated by M. Hempel, A. Kochendörfer and E. Hillnhagen* in tests on single crystals, specimens containing two or three crystals and polycrystalline material. The large crystals were obtained by the recrystallisation of strained iron containing less than 0·006 per cent of carbon. Their orientation was determined by the Laue reflection method, and the test pieces used for the determination of Wöhler curves were polished electrolytically in a perchloric acid-acetic anhydride bath in order to remove the effects of machining and the cold-worked surface layer. Tests were made on flat specimens in a Schenck alternate bending machine at a frequency of 1500 alternations per minute.

The corresponding values of stress and endurance for the single crystals gave a single Wöhler curve independently of their orientation. On the basis of a limiting endurance of 50×10^6 alternations, the fatigue strength of electrolytically polished α-iron single crystals was ±9·5 kg per square millimetre, that of the polycrystalline iron ±12·5 kg per square millimetre. The first value coincides approximately with the 0·2 per cent yield strength ascertained in static tests on the single crystal; the second lies about 18 per cent below the 0·2 per cent yield strength of the polycrystalline material. The tests resulted in the following ratios :

Ratio	Single crystal	Polycrystalline material
Fatigue strength : 0·2 per cent yield	1·03	0·83
Fatigue strength : tensile strength	0·54	0·44

Mechanically polished and etched specimens possessed a higher fatigue limit than the electrolytically polished specimens on account of the lattice disturbance at their surface.

Tests on specimens consisting of two or three crystals showed that the position of the grain boundary had a great influence on the fatigue strength. In specimens in which the grain boundary was situated at right angles to the direction of stress (Fig. 1 *a*), the early formation of an intercrystalline fatigue crack reduced the endurance in comparison with that of a single crystal. If the grain boundary lay parallel to the direction of stress (Fig. 1 *b*), fracture occurred at a considerably greater number of alternations at a higher stress than in a single crystal, on account of the strengthening effect of the grain boundary. Fracture occurred in specimens of the three types shown in Fig. 1 under the following conditions :

Specimen	Stress	Endurance
(*a*) Two crystals	±10·8	$0·72 \times 10^6$
(*b*) Two crystals	±15·0	$1·53 \times 10^6$
(*c*) Three crystals	±14·6	$1·67 \times 10^6$

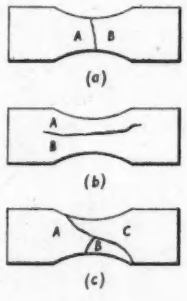


Fig. 1—Direction of the grain boundaries in the specimens studied: (*a*) perpendicular; (*b*) parallel, and (c) at different inclinations to the direction of stress

The investigation also included metallographic studies of the influence of crystal orientation and stressing conditions on the formation of slip bands at the surface of the alternating test specimens and their importance in leading to the appearance of fatigue cracks. The paper reporting these results† is illustrated by a great number of photographs taken with the optical and electron microscopes and showing the stages leading to fatigue failure. The slip mechanism in the alternate bending fatigue test corresponded essentially with that operating in tensile testing. In both cases fracture started in the same system of slip planes and these determined the direction of the fatigue cracks. In two- and three-crystal test pieces the progress of fatigue fracture was influenced by the position of the grain boundaries in relation to the direction of stress. Electron microscope photographs of single crystals showed that under alternating stress the initial submicroscopical fissures on the surface gradually extended to form micro and macro cracks.

* *Archiv für das Eisenhüttenwesen*, July, 1957, page 417.
† *Ibid*, August, 1957, page 433.

Brinell Hardness Measurements

IRREGULAR or elliptical impressions are often formed as a result of some lack of homogeneity in the structure of the material. In measuring such impressions it is usual to take measurements in two directions at right angles and to estimate the hardness from the mean value. When the impression is elliptical the measurements should be made along the two axes of the ellipse. The effect of the position of these two cross measurements has been discussed by W. Wepner.* If the lengths of the axes of the ellipse differ by not more than 10 per cent from one another, the position of the cross measurements relative to the axes is not of great importance. On the other hand, attention must be given to see that the measuring directions are at right angles to one another; deviation from the perpendicular should not be more than 2 deg. If a greater deviation, up to 10 deg., is allowed, the cross measurements must coincide approximately with the principal axes of the ellipse.

Intercrystalline Corrosion Tests on Austenitic Chromium-Nickel Steels

DIFFERENT methods which have been proposed for testing the susceptibility of austenitic chromium-nickel steels to intercrystalline corrosion have been reviewed by H. Zitter,† who has made a study of them, with particular reference to the testing of welded steel. Special attention was given to three important methods of testing, viz. tests in a mixture of hydrofluoric and nitric acids, in nitric acid alone, or in a copper sulphate-sulphuric acid solution. Electrolytic etching in oxalic acid solution was also investigated. A difficulty arises because the preliminary treatment of the steel employed before subjecting it to the action of the acid solution frequently does not correspond with the conditions of temperature and time to which the steel is exposed in practice. The time during which a welded steel is within the dangerous range of temperature depends upon the welding process and the manner of welding. In the arc welding of sheet steel under 10mm thick it is less than three minutes. It is thus much shorter than the time specified for the preliminary sensitising treatment in tests for susceptibility to intercrystalline cracking. In testing actual welds it is, therefore, necessary to use a solution which is as discriminating as possible. The $HF\text{-}HNO_3$ solution was found to be the most sensitive to the presence of intergranular carbide. In this test the time-temperature region of heat treatment producing a condition which could be recognised as potentially dangerous was more extensive than in the $CuSO_4\text{-}H_2SO_4$ test. A very short time at the most effective temperature revealed a tendency to intercrystalline cracking in 18 : 8 chromium-nickel steel containing 0·07 per cent of carbon. Susceptibility to intercrystalline cracking is reduced by lowering the carbon content, but in arc-welded sheet, up to 10mm thick, of steels with different carbon contents, the $HF\text{-}HNO_3$ solution detected damage at a carbon content 0·03 per cent lower than in otherwise similar steels which passed the $CuSO_4\text{-}H_2SO_4$ test. The $HF\text{-}HNO_3$ solution was therefore recommended for the testing of welded steel specimens without subsequent heat treatment, whereas the $CuSO_4\text{-}H_2SO_4$ solution, for which the preliminary heat treatment at 650 deg. Cent. would be more lengthy, was regarded as more suitable for testing specimens of unwelded steel.

* *Archiv für das Eisenhüttenwesen*, April, 1957, page 237.
† *Archiv für das Eisenhüttenwesen*, July, 1957, page 401.

Electronics Research Laboratory

Open days were held recently at the Mullard Research Laboratories, Salfords, Near Redhill, Surrey. These laboratories constitute a centre for the company's research efforts on radio, electronics and allied subjects. With the recently completed extensions the Salfords laboratories now accommodate a staff of about 700, of whom 175 are graduate physicists or engineers. The work is classified, broadly, into seven divisions: they are concerned, respectively, with solid state physics, microwave tubes, special tubes (such as image converters and storage tubes), electronic apparatus, telecommunications, applications, and engineering and other services. Some of these activities are briefly referred to here.

THE scope of the Mullard research laboratories at Salfords, Surrey, has been widened considerably by the completion of extensive new buildings. A four-storey office block, flanking a two-storey laboratory building, part of which can be seen in the accompanying illustration, forms the main extensions. The additional space available to the laboratories proper is about 18,000 square feet, and a further 10,000 square feet is used for offices and a large technical library. Of the total staff of 700 at the Salfords laboratories about 175 are graduate physicists or engineers.

Part of the laboratories' effort is concerned with basic research into materials, processes and techniques that are of interest to the various manufacturing divisions of the company. Another part of the work is devoted to the advanced development (to the prototype stage) of electron tubes, semi-conductor devices and electronic equipment; an important adjunct of this work is the customer advisory service, which handles fundamental problems stemming from the use of the company's products—particularly those (such as valves and cathode-ray tubes) that form components of other manufacturers' products.

Yet another part of the research effort is that done for Government departments. So close is the relationship with these departments that the laboratories often function as an extension of the experimental facilities of a Government scientific establishment. Close liaison with the science and research departments of the universities is also fostered.

The activities of the laboratory fall broadly into seven divisions, which are concerned respectively with (1) solid state physics; (2) microwave tubes; (3) special tubes, such as image converters; (4) electronic instruments and apparatus, including industrial control gear and ultrasonic equipment; (5) telecommunications; (6) applications, and (7) engineering and other services.

Solid State Physics

The programme of the solid state physics division, under Dr. K. Hoselitz, includes work on semi-conductors, low-temperature phenomena and magnetic materials.

In the semi-conductor laboratories work is in hand on the purification of semi-conducting materials and on the growth of crystals. The bulk properties of these materials are being studied with the help of optical and electrical measurements and ultrasonic techniques. An important part of this programme is concerned with the physics and chemistry of surfaces.

High-Frequency Transistor.—With the growing application of transistors in radio and electronic engineering one of the main needs is to increase the upper frequency limit at which transistors can be used. The junction transistor consists of a single crystal of germanium or silicon which is made of three regions of alternate conductivity, either *n–p–n* or *p–n–p*. A narrow central base region of one conductivity type is sandwiched between two regions of opposite type. A leading parameter that determines the upper frequency limit at which the device can operate is the thickness of the central base region. The smaller this dimension, the higher the "cut-off" frequency. Research in this laboratory in the past few years has led to the development of the process of alloy diffusion, which enables very narrow base width to be achieved in a comparatively simple way. In the alloy-diffusion process as applied to germanium a small mass containing both *n*-type and *p*-type impurities is heated and kept molten in contact with one surface of a *p*-type crystal. The *n*-type impurities diffuse faster in germanium than *p*-type, and the base width is determined by the difference in the diffusion depth of the two impurities, and is, therefore, accurately controllable. The *p*-type impurity is so chosen that on cooling and solidification of the molten mass the recrystallised region is a good *p*-type emitter region. Thus a *p–n–p* transistor is made in one basic step.

The process outlined here has been adapted in detail to meet a specific requirement of a transistor for amplification at 100 Mc/s. Developmental samples have the following average characteristics.

Average Characteristics of Developmental Samples of High-Frequency Transistors

Parameter	Value	Remarks
Cut-off frequency ($f_{\alpha b}$)	150–200 Mc/s	This can be varied over a wide range by altering the manufacturing conditions
Emitter to base depletion layer capacitance	20–30pF (at zero bias)	This substantially reduces the value of $f_{\alpha b}$ when the emitter current is less than about 2 mA
Emitter to base breakdown voltage	1·5V to 2V	—
Punch - through voltage	>50V	—
Collector capacitance	3–4 pF (−6V bias)	—
Feedback base resistance	15–25Ω	—
Noise figure ...	2–4 dB between 50 kc/s and 20 Mc/s	—
Neutralised power gain at 100 Mc/s	10 dB	—
Base to collector current gain (α')	200–300	At emitter currents of less than 100μA, α' decreases rapidly

The emitter and collector reverse currents are satisfactory.

Using a torque magnetometer to measure the anisotropy constants of ferrites

New semi-conductor compounds are being investigated and crystals are being grown either by the melt or by sublimation from the vapour phase, in some instances at temperatures above 2000 deg. Cent. The resulting materials are being studied electrically and optically and by metallurgical and chemical means.

In the low-temperature laboratory work is being started on a programme of measurements down to temperatures below 4 deg. absolute. The techniques used in this work will include nuclear and electron resonance magnetic spectroscopy.

The magnetic laboratories are mainly concerned with the ferrites or magnetic oxides and work is in progress on all aspects of the synthesis, by various methods, of single crystal ferrites.

Magnetic oxides, developed in the Philips Laboratories in Eindhoven during the last war, are the only magnetic materials which are electrical insulators and hence can be used in many applications where high permeability is required at high frequencies, for example in transformers and coils in radio and television receivers and telephones. These materials are usually used in the ceramic form, that is, the magnetic parts are produced as pressed parts from fine powders which are subsequently fired at a high temperature. Thus they consist of very fine grains with random orientation of the crystal axes. Many magnetic properties of magnetic materials depend on the direction relative to the crystal axes in which they are measured, and, to study this dependence (as illustrated here) and to eliminate the effects of grain boundaries, single crystals are required. It is difficult to make good single crystals of magnetic oxides because of the high melting point and the complex chemical composition of these materials, but the laboratory has a substantial research programme devoted to this subject.

Among the crystals that have been made are manganese ferrite ($MnFe_2O_4$), cobalt ferrite ($CoFe_2O_4$), mixed manganese-cobalt ferrites,

nickel oxide (NiO), magnetite (Fe_3O_4), and a few others. Their melting points are between 1550 deg. and 1900 deg. Cent. Two methods are used to make the crystals. In the first, the Verneuil, or flame fusion method, finely powdered raw material is melted by falling through an oxy-gas-flame on to a pedestal standing in the flame, thus slowly building up a boule of material, the top of which is kept molten in the flame. The boule is slowly lowered as it grows, to keep the molten top always in the hottest part of the flame. In the second method the materials are fused in a platinum crucible in a high temperature electric furnace and crystallised by very slow cooling. Crystals grown by the two methods are about 1cm diameter and 5cm to 10cm long.

The crystals so produced are used for research on the ferromagnetic properties of these oxides, including the phenomena of magnetic resonance which occurs when a piece of ferrite is placed in the path of microwave radiation and a magnetic field is applied. At a critical value of the field the piece of ferrite absorbs microwave radiation strongly : this effect is due to the occurrence of gyromagnetic resonance of the electrons which carry the magnetic moment in the ferrite. Under certain conditions the phenomenon of magnetic resonance can be used to produce power amplification of microwave radiation, and for this purpose single crystal pieces of ferrite are essential. Thus it is possible that the single crystals which at present are mainly used for research will become of great practical value in the field of microwave amplifiers.

Thin magnetic films, mainly produced by vacuum deposition, are also being studied in these laboratories.

Microwave Tube Division

In the microwave tube division under Mr. N. J. Chanter there is a high-vacuum laboratory in which studies are in progress of the residual gases in valves and of the poisoning effect of these gases on oxide cathodes. The evacuation techniques in use yield pressures of 10^{-11}mm Hg at which the residual gases are reduced to 0·01 per cent of those normally present in a vacuum tube. At these pressure levels it is possible to study the effects of very small quantities of gases expelled, on heating, from the materials used in valves. Identification of the gases withdrawn from the valve assemblies is effected by a mass spectrometer covering the mass range 2 to 200.

A separate laboratory in this division is occupied with research and development of travelling-wave-tube amplifiers for use in communications in the microwave bands. Work is being done at frequencies ranging from 3600 to 20,000 Mc/s on low-noise amplifiers, voltage amplifiers and power amplifiers up to levels of 5W. Special attention is being given to the problems to be faced in the production of travelling-wave-tubes as reliable and practical equipments. In an associated laboratory a group is doing research on travelling-wave amplifiers at millimetric wavelengths. Hitherto most of this effort has been directed at the 8mm region, but methods suitable for shorter wavelengths are being investigated.

Elsewhere work is being done on the development of magnetrons for radar and special purposes and on a travelling-wave tube for use in communication links. In the adjoining klystron laboratory the programme includes the study of high-gain multi-cavity klystron amplifiers having peak powers ranging from a few watts up to 250kW, suitable for phase-coherent radar systems. A team has also been investigating high-power pulsed travelling-wave tubes, and the allied problems of producing suitable electron beams for these tubes have been examined.

Special Tubes Division

Image converters, storage tubes, electron emission and gas discharges are among the subjects that come within the scope of the special tubes division under Mr. C. H. Tosswill. Electron tubes developed in the image converter laboratory consist generally of a diode incorporating a photo-emissive cathode, a focusing device and a fluorescent-screen anode. Such an arrangement can be put to various uses. For example, it can transform ultra-violet or infra-red images into visible image. It can operate as a camera shutter at speeds greatly exceeding those attainable by mechanical means ; exposures of the order of 3×10^{-9} seconds are quite practicable. In the accompanying illustration

Preparations for the process of evaporating a metallised film for an image converter tube

we show an operator making preparations for evaporating a metallised film for an image converter tube.

The electron emission laboratory is studying some aspects of the behaviour of electrons at solid surfaces in evacuated or gas-filled tubes. For example, an examination has been made of the photo-emission of electrons from surfaces in trigger tubes and gas discharge stabilisers. The current programme of research includes studies of the transmission of electrons through thin films and of the effect of electron bombardment on chemical reactions.

The gas discharge laboratory is concerned, generally, with the gas discharge properties which determine the operation of equipments such as voltage reference tubes, thyratrons and counting tubes. Here, the results of recent fundamental research are being used to account for, and to overcome, the limitations of existing commercial tubes. For example, gas clean-up in inert thermionic discharges is being studied.

Electronics Division

Among the interesting laboratories in the electronics division headed by Mr. J. H. Richards, is one devoted to special problems in servo-mechanisms, telemetering and in the measurement of physical properties. An example of the activities of this special problems laboratory is in the improvement of the signal-to-noise ratio of a radar receiver. The principle of the method is to use a mercury delay line to store each of the signals received from a distant target, to integrate them and then display the result, in which there may be a tenfold improvement in the amplitude of the signal compared with that of the random noise. In the apparatus now being developed magneto-strictive wire will replace the existing mercury delay lines for the storage of the wanted signals.

In this division there is a computer ferrites laboratory which is specifically concerned with applications of ferrite cores in computers. For example, there is a machine for the automatic testing of " Ferroxcube " memory cores. These small cores, or washers, have an outside diameter of 0·080in and are made from a grade of " Ferroxcube " having a rectangular hysteresis loop and are primarily intended for use in coincident-current magnetic storage systems or memories. In this testing machine the cores are fed into a chute and are loaded singly on to a multi-station rotary carrier on which each core in turn is subjected to a test sequence. The test equipment compares the outputs obtained from the cores with those obtained from a reference core when both are subjected to a sequence of current pulses simulating the conditions encountered in a magnetic matrix with a two-to-one selection ratio. Current pulses are applied to a single conductor threading the cores once only and the output e.m.f.s are induced in a second conductor. The machine handles the cores automatically at the rate of four per second.

Another laboratory is concerned with the application of electronics to industrial processes. A good example of its work is an automatic co-ordinate positioning machine which has been developed for marking out sheet metals. In this machine the tool head is moved over the work table in increments of 0·001in and the movements can be controlled by dial settings, punched cards or tape.

In the magnet laboratory nuclear resonance techniques are being used to plot the fields of large magnets and measure their uniformity. This method of measurement depends on the fact that the behaviour of various nuclei in a magnetic field is conditioned by the strength of the field and is particularly sensitive to resonance effects. With methods and equipment developed in these laboratories it is possible to make measurements to an accuracy of 1 milligauss in fields of some thousands of gauss. Conversely a known magnetic field can be used as a very sensitive means of detecting the presence of, and identifying, certain nuclei provided that their resonance characteristics are known.

Telecommunications Division

The telecommunications division under Mr. R. M. Godfrey houses the linear accelerator laboratory as well as laboratories for radio communications and for decimetric, centimetric and millimetric radar.

The linear accelerator laboratory is arranged for the development, construction and application of travelling wave linear accelerators. The applications include radiology, medical and nuclear research, industrial radiography and irradiation. A 4MeV linear accelerator is installed in the laboratory for experimental design work and application studies.

One of the interesting applications of such a machine is in the irradiation of long-chain polymers to cause breaking of some of the carbon-hydrogen bonds and consequent unbalance in the electrical structure. Such an unbalanced molecule can then form a cross link with a neighbouring molecule. The extent to which cross linking occurs depends upon the amount of irradiation energy absorbed. In polyethylene, which is a typical long-chain polymer, the effects of even a small percentage of cross linkage is very marked. Whereas ordinary polyethylene softens below 100 deg. Cent. and is molten at 115 deg. Cent., irradiated polyethylene withstands boiling water, is usable above 250 deg. Cent., and retains its mechanical strength up to 400 deg. Cent. Irradiation greatly increases the resistance of polyethylene to hot solvents, such as acetone and trichlorethylene, but does not significantly alter its electrical properties. Its elastic moduli can be increased by relatively high doses. It is possible to produce polyethylene ranging from very soft to glass-hard by suitable irradiation of one sample.

Vulcanisation of rubber, which normally involves additions such as sulphur and the application of heat, can also be effected by irradiation alone, the product being available for immediate use. This process is especially useful in the case of silicone rubbers as it avoids the need to eliminate harmful by-products.

We learn that for work of this kind the 4MeV linear accelerator could treat 30 lb to 40 lb of polyethylene products to a level of 10 Megarad at a cost of about 1s. 6d. per pound—that is, the running costs of the machine are of the order of £2 per hour.

An interesting equipment developed by the telecommunications division is that of a Q-band

pressurised airborne radar. The history of radar is characterised by the progressive exploitation of the shorter wavelength end of the radio spectrum. As the operating wavelength of a radar is decreased, an aerial of given size will provide greater resolution of target detail. At millimetre wavelengths it is possible to achieve a resolution more nearly approaching that of the human eye.

The equipment that was exhibited during the laboratory's open days represents a significant advance in millimetric techniques. It has been developed for the Ministry of Supply as a general-purpose Q-band transmitter/receiver. The major units are the TR-head, modulator, power supply and control unit, and have the following characteristics :—

Modulator ...	Line type, hydrogen thyratron ; peak power output greater than 200kW ; pulse length 0·2 microsecond, p.r.f. variable.
Transmitter ...	Pulse magnetron, peak power greater than 30kW ; duplexer for common aerial working ; frequency, 36,000 Mc/s band (8mm wavelength).
Receiver	Balanced crystal mixer and low-noise head amplifier ; combined mechanical and electronic automatic frequency control for klystron local oscillator.
Environment ...	Pan-climatic design : pressurised containers with integral heat enchangers.
Construction ...	Rugged construction for high accelerations ; sub-assemblies detachable for ease of servicing.
Power supplies	115V, 400 c/s, three-phase and 24V d.c.

Engineering Division

The engineering division under Mr. G. Birkbeck has design and drawing-offices and workshops to serve all the laboratories at Salfords. It has its own engineering laboratory where studies can be made of advanced techniques, such as printed circuitry, component potting and the application of adhesives. During our visit we saw a demonstration of ultrasonics used as a method of accelerating etching in a printed circuit process. Work is also being done on ultrasonic drilling and on methods of slicing wafers of semi-conducting materials in the manufacture of transistors.

The engineering workshops include machine shops, sheet metal, wiring, coil winding and finishing shops. All mechanisms, precision assemblies, components for linear accelerators and microwave tubes, and special jigs and tools, are made in the machine shop. Typical examples of the standards of workmanship are to be seen in the manufacture of linear accelerator components ; the travelling waveguide is built up of a number of copper cells which are machined to ±0·0003in before being soldered together with rings of copper eutectic alloy.

The engineering division also operates a measurements and instrument maintenance department and a reference library.

Geological Survey in the Colonies

The first ten years of work—from January, 1947, to December, 1956—of the Directorate of Colonial Geological Surveys is reviewed in a report prepared by Dr. F. Dixey, its director, and published by H.M. Stationery Office. A large increase in basic geological mapping has been achieved in the various territories (more than twenty) with which the Directorate is concerned.

The advent of aerial photography and topographical mapping (by the Directorate of Colonial Geodetic and Topographic Surveys) has also been a change of fundamental benefit to the geological surveys, allowing the geologists to concentrate on their own special work.

A detailed account of progress in each of the territories is given in the report. Apart from basic geological mapping, important results have been achieved in mineral investigations, and an impressive list of discoveries, many of them now either in production or being actively considered for production, is given. Another field in which the Directorate has been active is that of engineering geology, and in particular its application to water supply. Assistance with various well-known civil engineering projects is recorded, and much valuable work has been done. Specialist services which the Directorate has formed include a section concerned with photo-geology and geophysics and a mineral resources division.

20MVA Transformer for Arc Furnace

A NEW electric arc furnace with a 20ft hearth diameter and a capacity of 80 tons is in service at the Stocksbridge works of Samuel Fox and Co., Ltd. as illustrated here. It is expected to produce between 1400 tons and 1600 tons of alloy and stainless steels per week and will raise the annual output of special steels at this works from 300,000 tons to nearly 400,000 tons.

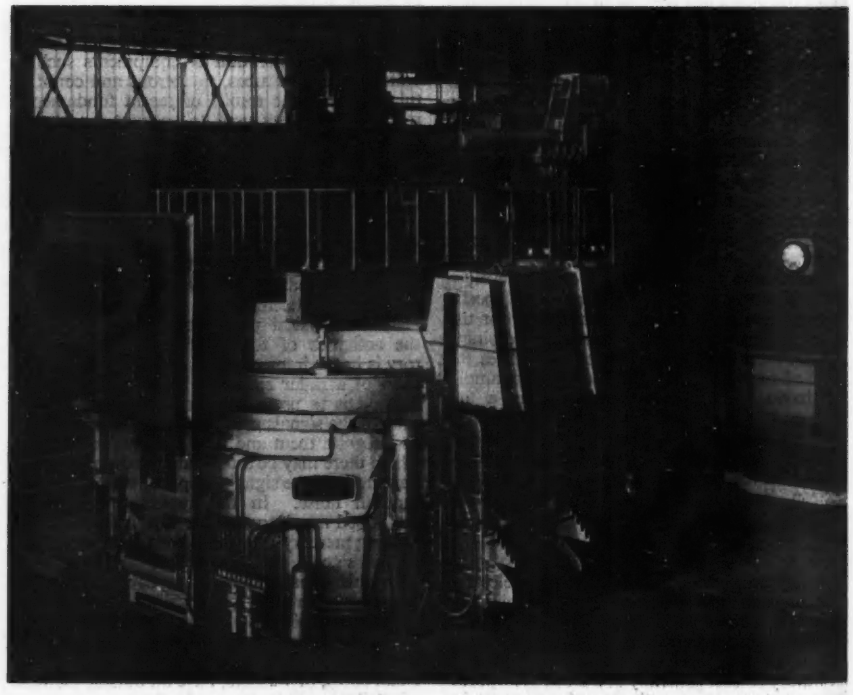
This furnace, like the 19ft hearth diameter furnace, commissioned at the same works three years ago, was made by Birlec, Ltd., Erdington, Birmingham. Both installations are top-charged direct arc furnaces with three 20in diameter electrodes and can accommodate an induction stirrer in the stainless steel shell base. The two furnaces are installed in the same melting shop, the control rooms and basement for electricity and other services being sited between them.

To provide for the increased production capacity the three bays of the melting shop have been extended by 144ft, extra casting pits have been built and a second charging basket and transfer carriage have been installed. Parallel extensions have also been made to the raw material stockyard, to the capacity for preparation of ferro-alloys and to the rail traffic facilities for handling the increased volume of raw materials required by the works.

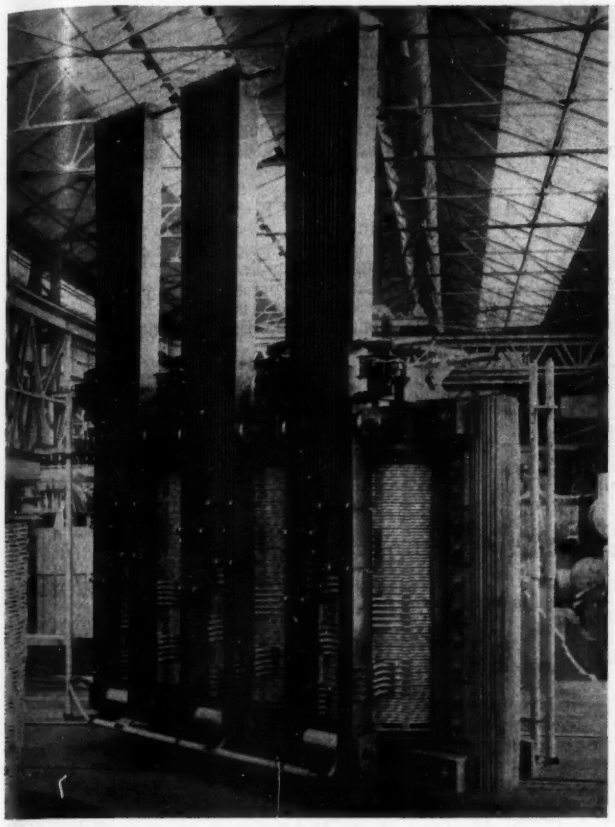
The 66kV, 20MVA transformer and the air-blast switchgear controlling the power supply to the new furnace were made by the English Electric Company, Ltd., Stafford. The transformer is of special interest, in that it is the largest of its kind to be made in Great Britain and the first to operate directly from a 66kV supply. Like the 15MVA English Electric transformer that supplies the other Birlec furnace, in the same melting shop, it uses on-load tap-changing gear.

By the use of on-load tap-changing equipment on the transformer the frequency of operation of the main switchgear is reduced to an annual figure of the order of 5000 to 6000, which is within the capabilities of the 66kV air-blast switchgear installed, and direct operation from the local 66kV supply of the Yorkshire Electricity Board is made feasible. In addition, on-load tap-changing equipment adds considerably to the ease of operation and makes possible a much finer degree of control of the furnace. Also, by permitting an uninterrupted flow of power, it tends to shorten the melting time, thereby making a further contribution towards reducing

Completed 66kV, 20MVA transformer for the 80-ton arc furnace. The enclosure for the on-load tap changing equipment is on the left and the high-voltage cable box is on the right



The new electric arc furnace at the Stocksbridge works of Samuel Fox and Co., Ltd., has a capacity of 80 tons and a hearth diameter of 20ft. The control room is on the right



Low voltage side of main unit of 66kV, 20MVA arc furnace transformer. The current transformers for electrode control can be seen

the cost per ton of steel that is produced.

Compared with the earlier 15MVA installation, the same basic design has again been used in that two transformers are mounted together in one common tank, one transformer acting as a voltage regulator, the other as the main step-down transformer to furnace voltage. The voltage regulator is auto-connected, tappings are brought out from the windings and the on-load tap-changing equipment is connected to them. The variable output voltage from this transformer is fed directly into the primary windings of the main step-down transformer, which is free from tappings. The secondary windings of the main transformer supply the very heavy current at low voltage to the furnace electrodes. All ends of these windings are brought out (as shown in our illustration above) and externally connected in delta above the tank.

The principal reasons for the adoption of this "double-unit" construction are, first, that no voltage greater than that of the incoming supply is produced anywhere in the equipment,; secondly, the fact that there are no tappings on the transformer directly connected to the furnace considerably increases the mechanical strength of the windings, which is very desirable because of the very heavy and frequent overloads during the melting period.

The addition of semi-automatic power factor correction is also possible.

This refinement was not incorporated on the 15MVA transformer for the first furnace, but has been provided on the 20MVA transformer for the new 80-ton furnace. It takes the form of tertiary windings on the main step-down transformer for connection to a 7000 kVAR capacitor bank. The voltage available from the tertiary windings has a maximum value of 11kV, and, because of the common primary winding, this voltage varies in direct proportion to that being supplied to the furnace electrodes. Thus, as the voltage to the furnace is reduced, the voltage to the capacitors is simultaneously reduced and the effective capacitance in circuit is decreased, thereby eliminating the risk of over-correction at low load.

The on-load tap-changing equipment fitted to the 20MVA transformer is basically similar to that fitted to the 15MVA transformer, except that it is designed to operate at the higher voltage of 66kV. Reactor transition is used, the continuous rating of this kind of on-load tap-changing being advantageous on an installation where reliability is of primary importance, since no standby supply is available. Furthermore, a mechanically stronger winding is possible with this kind of tap-changing equipment, since the number of tappings to be brought out from the regulator transformer windings are only half the number of the low voltages available. The on-load tap-changing equipment is motor driven and is controlled remotely by means of a pre-selective voltage control switch in the furnace control room.

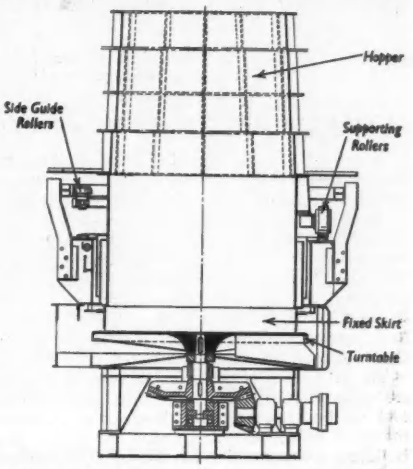
One of the major problems that had to be solved in the design of this transformer was that, despite the rating of 20MVA and the incoming supply of 66kV, it had to be accommodated in a substation the same size and a mirror image of that provided for the 15MVA, 11kV transformer supplying the first furnace. The limited height was achieved by using five limb cores for both the regulating and main transformers. To retain the leakproof method, common to all English Electric furnace transformers, of bringing out the l.v. bars through the oil conservator, the whole of the conservator and the tank cover of which it forms an integral part, were made of non-magnetic stainless steel. By this means a further reduction in height was brought about as it was possible to reduce the distance between the external l.v. delta connections and the transformer superstructure without any risk of local overheating. All the equipment is contained in one common tank and the various tank fittings and refinements, including winding temperature indication and Buchholz protection, associated with modern transformer practice are incorporated. Cooling is by duplicate oil-water heat exchangers, either of which is capable of dissipating the full load transformer losses. The service weight of the transformer, oil cooling equipment and auxiliaries is 97½ tons.

Slurry Handling at Barony Power Station

PERHAPS the most interesting aspect of the Barony power station,* which is situated next to the Barony colliery in the Ayrshire coalfield, is its use of washery slurry for fuel. This, the lowest grade of residual coal, has a gross calorific value of 6450 B.Th.U. per pound, a moisture content of 30 per cent, and 25 per cent ash; most of it passes through a ¼in mesh British Standard sieve. For bunkering, feeding and pulverising this putty-like matter at Barony, handling methods not previously employed in Britain have found application.

According to some estimates, there are more than 6,000,000 tons of slurry in ponds throughout the country. This unsaleable residue exists because the increased mechanisation of mining has caused a higher proportion of dirt and fines to be brought to the surface, and the plant used to convert this into marketable form cannot deal successfully with the whole of it. So-called slurry varies from district to district. In the East Midlands, for example, it is coal up to ¼in in size. At Barony, however, the name refers to the washery residue that is grabbed from ponds after settling out of the water. This sort of slurry is more difficult to handle than to burn.

The main principle to be observed in handling the paste is to keep it incessantly on the move, and special techniques to this end have been developed for use at Barony.† The slurry is brought by rail, but tipplers cannot be used because of the peculiar pouring behaviour. Four-ton Goliath cranes grab the slurry out of the wagons and transfer it to the main store. The latter holds more than 4000 tons. There is also space for about 550 tons of slack coal, since the latter is sometimes mixed with the slurry in the boiler house. Four rotary hoppers feed the slurry on to a belt conveyor. These hoppers, which are the heart of the feeding system, have sloping sides with reverse batter, as shown in our illustration. The bottom of the hopper is a motor-driven turntable. Slurry is continuously sliced off the table by a plough carried on a fixed skirt, and the pieces fall on to the belt. The body



Sectional elevation showing the general arrangement of one of the rotary hoppers used to handle washery slurry at Barony power station

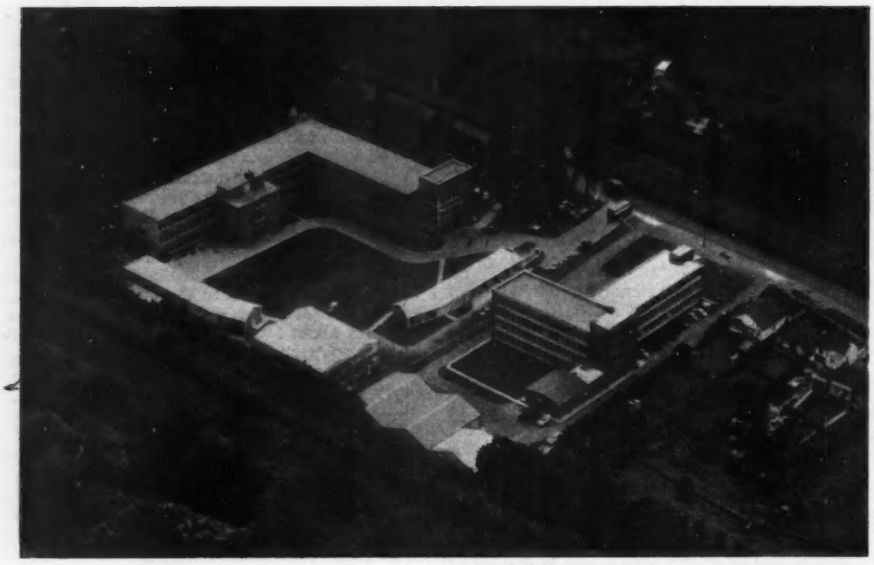
of the hopper is mounted on heavy roller tracks and is free to rotate, so avoiding the shearing constraint that the sticky slurry would otherwise exert on the sides. Such constraint would require high power to overcome, and could jam the hopper with stationary material skidding on the turntable instead of rotating against the plough.

The conveyor takes the slurry from the hoppers to the mixer house. Different grades of slurry can be fed from the individual hoppers and mixed in any proportions. Slurry enters the house near the top, under magnetic separators that remove tramp iron, and is delivered over-end from No. 1 conveyor to No. 2. The latter is a short reversible belt, which delivers to screw-type paddle mixers. The mixers, in turn, deliver to No. 3 conveyor. No. 2 is reversed when mixing is not required, and then slurry is delivered over-end directly to No. 3. This arrangement corresponds to the by-pass chutes and flap valves that would be used with normal coal. No. 3 conveyor rises to a junction tower, where a right-angular bend is made to approach the boiler house. In the tower the slurry is delivered over-end to No. 4 conveyor, down a short straight chute fitted with a vibrator. No. 4 takes the slurry to the boiler house for transfer to a reversible shuttle conveyor that can deliver to any one of the hoppers (also rotary, but smaller than those previously described) feeding the pulverisers.

Slack coal is conveyed in an orthodox manner and is distributed to bunkers in the boiler house. It is released to the mills when a mixture of slack and slurry is wanted for firing. While the slurry plant runs continuously, the slack plant can be shut down when the bunkers are filled.

* Officially opened on October 11. The output is 60MW from two standard G.E.C. sets, using steam whose conditions at the stop valve are 600 lb per square inch and 850 deg. Fah.

† By Babcock and Wilcox, Ltd.



Aerial view of the research establishment opened last week at Whyteleafe, Surrey. It is built to concentrate the design and development of Powers-Samas computers in one establishment

Computer Research Establishment

VISCOUNT KNOLLYS, chairman of the Vickers group, spoke at the inauguration of the Powers-Samas Research Establishment at Whyteleafe, Surrey, on October 16. His speech followed the welcoming address by Colonel A. T. Maxwell, chairman of Powers-Samas Accounting Machines, Ltd., who stressed the seriousness of the present shortage of trained technical people. Lord Knollys supported him in his plea that parents and the teaching profession should encourage the choice of a scientific education.

The setting-up of the establishment at Whyteleafe has enabled the design offices, workshops and various research and development departments to be concentrated under one roof. The buildings are reported to cover over 50,000 square feet, and are on a site of nearly three acres. The main preoccupation of the staff is the investigation of a number of computer storage systems, though work on the improvement of existing products plays a considerable part. Equipment includes stroboscopic and cathode-ray tube instruments and a high-speed camera capable of 3000 frames per second. This apparatus is used for the study, *inter alia*, of the more rapid motions occurring in punched-card machines. As an example of the sort of new technique produced by its research division, the company quotes the oscillating stylus used in the "Samastronic" accounting machine. This device is said to print characters at the rate of 700 per second.

North of Scotland Hydro-Electric Board

THE North of Scotland Hydro-Electric Board has published a constructional scheme (No. 47) to provide for additions to the existing schemes on the River Moriston, in Inverness-shire, and at Storr Lochs, in Skye, which will increase their output by a total of 13,500,000 units of electricity each year.

In Glen Moriston, the output of the Ceannacroc and Doe power stations would be increased by 12,200,000 units by extending the catchment area feeding these two power stations to bring in waters from the Allt a' Chroinn, the Allt na' Muic and the Allt Bail 'an Tuim Bhuidhe, small burns on the north side of the glen. Provision is also made in the scheme for forming small reservoirs at Loch Liath, Loch na Stac and Loch a' Chrathaich to improve the regulation of flow to the Livishie power station of the Moriston scheme. The Ceannacroc power station is already in commission; no work has yet been done on the Doe and Livishie power stations. The scheme was described in THE ENGINEER of October 5, 1956.

At Storr Lochs, in Skye, it is proposed to divert the headwaters of the River Chracaig into Loch Fada by the construction of two aqueducts. This would enable the Board to meet a request of the County Council of Inverness to release, for water supply, part of the yield from the Storr Springs and also enable the Board to increase the output of electricity from the original scheme.

Weldable Stainless Steel With High Strength and Low Thermal Expansion

A STAINLESS steel that is new in the sense that it combines favourable characteristics hitherto found only separately in different alloys, is announced by Firth-Vickers Stainless Steels, Ltd. The product of research and development pursued since 1953, it is claimed to fill a gap in the existing range of stainless steels in this country. Similar in type to certain American

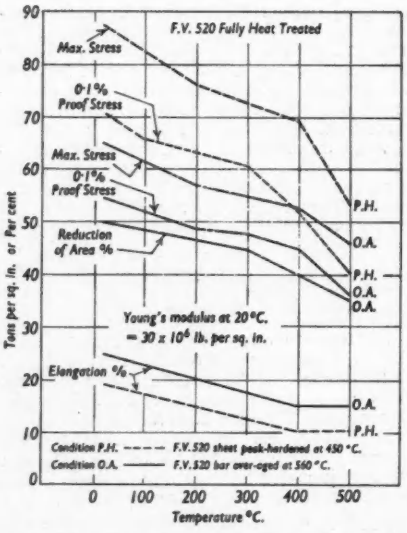


Fig. 1—Manufacturer's tensile test results for F.V.520 stainless steel

alloys, it is believed to be superior to them in some respects. A typical composition given by the manufacturer is C, 0·07 per cent; Cr, 16 per cent; Ni, 6 per cent; Cu, 1·5 per cent; Mo 1·5 per cent; Ti, 0·3 per cent.

The steel is stated to have high tensile and fatigue strengths, stainlessness equivalent to that of 18/8 steels, resistance to stress corrosion cracking, high impact strength at low temperatures, weldability, thermal expansion equal to that of mild steel, and a maximum service temperature of 500 deg. Cent. Named F.V. 520, the new alloy is said to weld readily without preheating. No precautions are necessary to avoid cracking. Heat-treatment after welding is not essential, but it is thought that post-welding stress relief at 550 deg. Cent. may be desirable. The material is available in sheet, bar or cast form. At a substantially lower cost it is expected to be competitive with titanium alloys for a number of applications. Most of the teething troubles with the alloy are reported to have been overcome, and it is now produced by continuous methods. Centrifugal casting technique is said

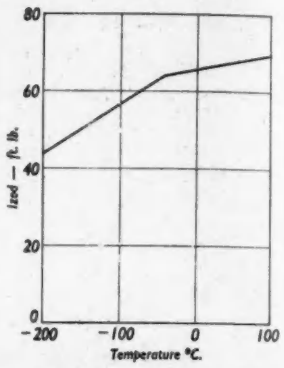


Fig. 2—Maker's "V"-notch impact test data for F.V.520 stainless steel bar, 65 tons per square inch tensile, over-aged at 560 deg. Cent.

to have been perfected, and static casting, though not perfected, is at an advanced stage of development. Bars and forgings are usually supplied fully heat-treated, but sometimes, in order to facilitate a critical machining operation, bars are delivered after an intermediate heat-treatment only. In the latter case the component must undergo further heat-treatment after machining. Coils of strip from 16 to 28 gauge are produced up to a metre wide, in a condition suitable for a number of forming operations. Although in this condition the reported 0·1 per cent proof stress is less than 25 tons per square inch, the steel work-hardens rapidly. Fairly uniform hardening across parts that have been either worked cold or not worked at all is possible by cyclic heat-treatment at temperatures of the order of 750 deg. Cent. Harder strip may be supplied for milder forming operations.

Creep test results as given by the maker are as follows :—

Total plastic strain (per cent)	Time (hours)	Stress in tons/sq. in. to give specified strain at a temperature of	
		400 deg. Cent.	500 deg. Cent.
0·1	300	27	12
0·2	300	37	16
0·2	1000	33	12

while Wohler fatigue test results on bar over-aged at 560 deg. Cent. are given as :—

±41 tons/sq. in.	50,000,000 reversals	Broken
±40 tons/sq. in.	100,000,000 reversals	Unbroken
±39 tons/sq. in.	100,000,000 reversals	Unbroken

for unnotched specimens in air at room temperature. With a drip feed of 3 per cent sodium chloride during the test the test endurance was:—

±25 tons/sq. in.	1,000,000 reversals	Broken
±24 tons/sq. in.	93,000,000 reversals	Unbroken
±22 tons/sq. in.	103,000,000 reversals	Unbroken

Tested in air with a notch of radius 0·031in, the material gave the following results :—

±24 tons/sq. in.	1,000,000 reversals	Broken
±23 tons/sq. in.	1,000,000 reversals	Broken
±22 tons/sq. in.	66,000,000 reversals	Unbroken

The coefficients of thermal expansion are quoted as :—

	Deg. Cent.
$11{\cdot}9\times10^{-6}$in per inch per deg. Cent.	20–100
$12{\cdot}4\times10^{-6}$in per inch per deg. Cent.	200
$12{\cdot}8\times10^{-6}$in per inch per deg. Cent.	300
$13{\cdot}1\times10^{-6}$in per inch per deg. Cent.	400
$13{\cdot}3\times10^{-6}$in per inch per deg. Cent.	500

Main bay for welded fabrications, with structural steelwork bay on the left and work preparation area on the right

Works for Heavy Welded Fabrications

At the beginning of this year the T.I. Group of companies formed a new manufacturing subsidiary, Old Park Engineering, Ltd., with a works at Holly Hall, Dudley, Worcs. The new company was founded on the former constructional department of the Round Oak Steel Works, Ltd. This department for many years was concerned primarily with the maintenance and repair of plant for the steel works, but in more recent times a steadily increasing amount of work for outside firms had been undertaken. The extent of this outside work, particularly for large weldments and fabricated steelwork, grew beyond the restricted capacity of the constructional department, and the need to meet the increasing demand led to the eventual decision to form a separate company with a new works. In laying out and equipping the works it was decided that its main concern would be the manufacture of heavy welded components to the special requirements of precision, rigidity and quality such as are called for by machine and engine builders, and steel works and process plant manufacturers. For this purpose large unobstructed floor areas are provided, which, with a maximum crane lifting capacity of 40 tons, facilitate the handling and assembly of the major component parts of heavy weldments.

The factory also produces the structural steelwork required for the mechanical handling plant produced by New Conveyor Company, Ltd., another T.I. subsidiary. The manufacture of these conventional bolted and riveted structures is, however, primarily a group arrangement to secure the most effective overall use of manufacturing capacity, and, as previously stated, the main interest of Old Park is in welded work.

The works has been built upon a large open site, which provides ample space for future extensions and has good rail and road access. It consists at present of two single-storey office blocks fronting the two adjoining main bays to be seen in the photograph we reproduce above. Each of these bays is 440ft long by 65ft wide, with a clear height of 32ft below the overhead cranes, which are of 10-ton and 30-ton capacity.

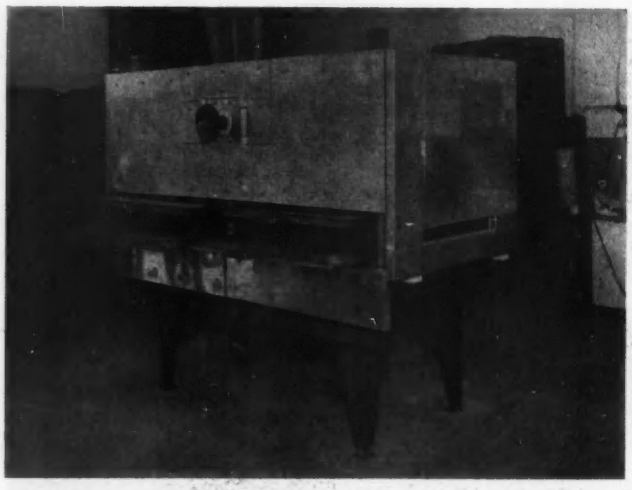
The left-hand bay illustrated is the structural bay, and alongside it on the outside of the building there is a large section stockyard served by an overhead crane. This stockyard is linked by rail with Round Oak Steel Works, where many of the sections are rolled. The sections pass straight from the stockyard to the head of the preparation end of the structural bay. The other two bays are used for welded fabrications, the small one on the right being a preparation area, which is connected at the far end to an open plate store. The main bay contains the initial assembly and final welding areas, and from this initial assembly area the work is transferred down the shop to welding areas, which are enclosed by sections of movable screens. These screens can be adjusted and arranged to suit the size and class of work in progress. Although a certain number of portable welding equipments have of necessity to be used in the bays the principal transformers for the heavy work are installed at the feet of the gantry columns between the two shops. Underground leads are being installed from these centres to strategic tapping points in the working areas.

Manipulating equipment is shortly to be installed to handle medium and lightweight weldments, and a stress relieving furnace at present under construction will have a chamber to take work up to 20ft long by 12ft by 10ft. The work preparation equipment includes flame profile cutting machines for plates up to 16in thick; plate rolls for 1in thick by 8ft plates; guillotines for work up to $\frac{1}{2}$in thick by 8ft; a 500-ton press brake for $\frac{1}{2}$in by 10ft wide sheets; and sawing, riveting, punching, drilling and other machines.

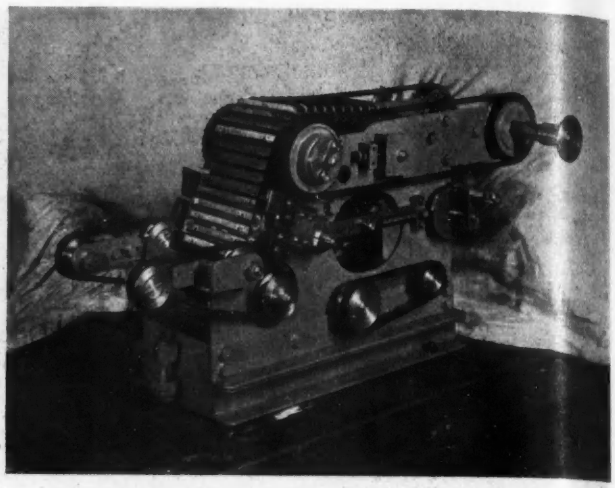
Welding Rod Drying Equipment

Machines for drying the flux coating on welding rods have been made for some years by the Spooner Dryer and Engineering Company, Ltd., of Ilkley, Yorks. We have received from the firm some notes on continuous dryers of this kind incorporating recent developments to give high production speeds. These dryers are used in conjunction with an extruding machine, from which the flux-coated and cut to length rods are delivered in an unbroken stream. It is pointed out that as far as the actual drying of the rods is concerned, the material forming the coating presents a problem in that it does not readily give up its moisture. Thus it is impossible to dry at a rate greater than that at which the material case hardens, and the speeds of drying, like the methods of distribution of the drying medium, may vary enormously. An arrangement suitable for one kind of flux may prove quite unsatisfactory for another kind, and it is to meet these difficulties that the firm has brought out new designs for conveyor and drying plant. An outstanding improvement in the design of the dryer is based on the recognition of the fact that in order to obtain the most satisfactory drying, not only should the temperature and humidity be zoned in the machine, but the force and direction of the air streams should be made variable for the different fluxes and rods.

The drying machine which has been developed may contain one or several drying units housed in a casing insulated against heat losses. Each unit consists of a fan which forces the air used as the drying medium through a built-in heating unit into two large interconnected pressure chambers. These pressure chambers are provided with nozzles or diffusers to direct the air streams on to or along the path of the rods, which are carried on the conveying chains running between the pressure chambers. The air is then returned to the fan for recirculation. Heat is



Small rod-drying oven showing the arrangement for the withdrawal of the frames, which are fitted with nozzles of yarying pitch and shape



Model of transfer and spacing head for feeding rods at spaced intervals on to drying-oven chain conveyor system

supplied by a gas or oil flame or electrical elements to the circulating air drawn into the eye of the fan.

The nozzles are mounted on a frame which can be easily removed from the pressure chambers for cleaning or changing with frames having nozzles of different pitch and shape.

A typical instance in the use of interchangeable nozzle frames is given as a drying unit with 3in spaced nozzles which could dry an ordinary flux or coating on a 10-gauge rod in three minutes. If the same flux was applied to a $\frac{1}{4}$in rod with a coating of about $\frac{1}{2}$in diameter, the drying characteristic would in all probability be completely changed. Twenty minutes or more would be required, perhaps at a lower temperature to prevent cracking. On the other hand, if a diffuser was used to lower the velocity of the air streams and possibly raise the temperature, the drying time might be reduced to little above that of the 10-gauge rod. Similarly, it has been found that the lighter rod does not dry so satisfactorily with the diffuser nozzle, the best results being obtained with the standard 3in spaced nozzle. The nozzle best suited to a particular kind of rod can be quickly determined in a small experimental oven, which has the same characteristics as the production machine and can be provided with frames carrying different kinds of nozzles.

The length required for the modern oven is considerable and a three-pass dryer has been designed to reduce the length to about one third of the single-pass machine. As already mentioned, a machine may consist of several dryer units, so that each unit can be operated at a specific temperature controlled at the fan. In the three-pass oven transfer points are provided for elevating the rods from one pass to the next higher pass. We illustrate a small oven, about 6ft long, with the frames carrying the nozzles partly withdrawn, for which purpose the panels of the outside casing have been lowered.

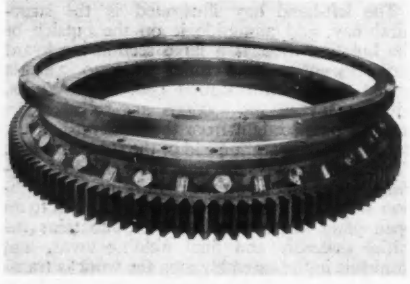
This small unit can be built up into a long continuous oven, each unit having its own fan and heater, in this case the heater being a gas burner.

In order to ensure that the maximum number of rods is accommodated in an oven it is important for the rods to be evenly distributed on the conveyor chains, and for this purpose a spacing head has been developed. As the rods arrive at this spacing head, shown in model form in our second illustration, they are transferred to the pair of short V-belts running at a slightly higher speed than the conveyor from the brushing head of the coating extruder brushing head. This conveyor is driven by a variable speed gear which is set to space the rods further apart. At the end of this conveyor the rods are picked up by an inclined slatted conveyor and deposited on a horizontal length of chain which transfers them on to the chain which carries the rods through the oven. The sprockets of the horizontal chains are driven from the wheels of the oven chains by a hexagonal shaft, and the horizontal chain drives the slatted conveyor through the speed varier. To ensure that only one rod is picked up by each slat a double cam is fitted, which can be adjusted by the hand control at the side of the head. In certain cases, especially when chains of $\frac{3}{4}$in pitch are used, two heads are provided, one for the large-diameter rods and one for the small. The change of heads can be quickly effected by unscrewing two wing nuts and withdrawing the hexagonal driving shaft.

Excavator Slewing Rings

PARTICULARS have been issued of a new slewing ring which has been designed by Priestman Brothers, Ltd., Hull, in conjunction with British Timken, Ltd., with a view to overcoming the limitations of the live roller ring on which an excavator superstructure rotates. The makers point out that this new "Cross-roll" bearing, as it is known, permits the transmission of upward as well as downward loads, so that operating loads are distributed throughout the ring. It also centralises rotation of the superstructure on the crawler frame and all its working parts are completely enclosed.

One of the new bearings is shown in the illustration below, and from the drawing we reproduce it will be appreciated how the

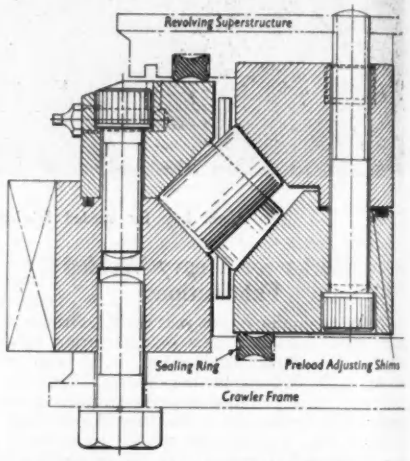


Excavator "cross-roll" bearing slewing ring, in which a double-row roller bearing is reproduced in a single-row construction

effect of a double-row bearing is reproduced in a single-row construction by alternately crossing the axes of rollers which run in the same diamond-shaped path. With this design alternate rollers carry upward and downward loads as required, and inclination of the roller axes allows transmission of radial loads required for centralising the inner and outer races.

The bearing consists of four race members spigoted and screwed together in pairs to form the inner and outer members of a diamond-shaped race section. The outer race member carrying the slewing spur gear teeth is bolted rigidly to the crawler frame, and the inner race is screwed to the bed-plate of the excavator. The tapered rollers are mounted in a special pressed steel spacing cage. On assembly, play in a bearing is adjusted by removing shims between the pair of inner race members. These shim sections are removed until "negative" play is obtained and the bearing is "preloaded." This preloading is an essential part of the design in order to combat the effect of shock loads met with in excavator service.

Bearings are packed with grease on assembly and this grease only requires replenishment at



Construction of "cross-roll" bearing

infrequent intervals, such as when a machine is being completely overhauled. To prevent the ingress of water or dirt, special cruciform rubber sealing strips are inserted between the inner race and the crawler frame and between the outer race and the bed-plate of the excavator.

We are informed by Priestman Brothers, Ltd. that machines fitted with prototype slewing rings have been subjected to the equivalent of many years' arduous work on an excavator test rig. As a result of these successful tests the "Cross-roll" slewing ring is now fitted as standard on the firm's "Tiger" V–X and "Cub" V excavators.

HIGH-SPEED, HIGH-POWER DYNAMOMETERS.—A range of dynamometers known as the "D.A." type, introduced by Heenan and Froude, Ltd., Worcester, is of a new design for dealing with very high powers and very high speeds. The full range of machines will cater for duties ranging from 350 h.p. at 17,000/45,000 r.p.m. up to 52,000 h.p. at 3500/8500 r.p.m. It is considered that these machines should have special appeal to manufacturers of gas turbines in the aircraft and industrial fields as well as to steam turbine manufacturers. We are informed that a number of prototype machines have already been tested under practical working conditions in the works of turbine manufacturers.

Passenger Vehicle Development

PNEUMATIC springing has now been developed for the rear suspension of A.E.C. "Routemaster" and "Bridgemaster" double-deck buses. The original coil springs have been replaced with bellows units of the Dunlop "Pneuride" system, described on page 60 of our issue of July 12 last. The application can be followed easily by reference to our illustration of the "Bridgemaster," credited to Crossley at the 1956 Commercial Motor Show, on page 393, September 21, 1956, and of the "Routemaster" between pages 417 and 418, September 24, 1954. 12in bellows are used, each connected by a pipe to an air tank of 1400 cubic inches capacity, and the working pressure varies between 35 lb per square inch with an empty vehicle and 65 lb per square inch with all seats filled. The periodicity of the suspension is found to vary between 98 and 100 cycles per minute, compared to perhaps 85 and 120 cycles per minute on the original design. Dunlop levelling valves are fitted at each side, with a delay period of 6–7 seconds, and provide a constant platform height: no difficulty has been found to arise from the use of a self-levelling suspension at one end of the vehicle only. The air supply is taken from a separate small reservoir, charged to brake system pressure and unable to drain the brake reservoir.

On this "Routemaster" coach interior heating is by a radiator below the destination display. The bonnet, of glass-reinforced plastic, hinges up toward the cab

The telescopic shock absorbers within the coil springs have been replaced by lever-action hydraulic dampers which are mounted on the transverse member joining the axle locating arms, so that they are themselves unsprung. A "Bridgemaster" with this suspension is now commencing a demonstration tour of the provinces.

Other developments of the original design are incorporated in the "CRL" (Coach-"Routemaster"-Leyland) prototype illustrated. This has a body which is interchangeable, so far as attachment points and tolerances are concerned with the A.E.C. "RM" vehicles, but the mechanical components are detailed and supplied by Leyland Motors, Ltd. The rear suspension remains by coil springs, but at the front torsion bars are used. The circular bars form the axis of rotation of the lower wishbone and run back to the cross member immediately behind the pick-up points of the engine suspension "cart." The engine is a Leyland O.600, with its output reduced from 125 h.p. to 115 h.p. at 1800 r.p.m. The operation of the gearbox is hydraulic, as on the other prototypes, but production vehicles of either class will have operation from the main air supply. The selector on the Leyland vehicle is that of Self-Changing Gears, Ltd., and differs from the "Automonocontrol" of the A.E.C. in that it is inhibited against upward as well as downward gear changes when the accelerator is released (see page 471, October 5, 1956). Unlike the S.C.G. control mentioned in the previous article, this version allows any indirect ratio to be manually selected at any forward speed, i.e. the driver can sacrifice the transmission in an emergency.

The driver's controls in this vehicle are, indeed, the most unusual feature of it. There are, of course, two pedals only, but both are on the right of the steering column. The accelerator moves at constant force throughout the fuel rack travel, but the further travel at a higher effort causes the speeds of all gear changes to be raised. The steering is, except temporarily on C.R.L.4, power assisted, again on a constant force system, but the ratio is as low as on manually steered vehicles to dispense with the need for safe modes of failure.

The body is modified for Green Line service; there are double jacknife doors on the platform, and the two double seats facing inwards above the rear wheels have been replaced by single seats facing at 45 deg. to the axis of the saloon two on the near side and one on the off side. The omission of one seat has allowed greater, luggage accommodation to be provided.

Heating and ventilation are provided at no cost in electricity or other power, fresh air being induced by the movement of the vehicle into the grille seen below the front destination box. An auxiliary radiator warms the air as necessary, the passage of engine coolant to it being controlled by the conductor. The driver has control of a blind cutting off the air flow as an anti-freezing measure. (London Transport use water in their cooling systems at all times.) The main radiator is in the revised "Routemaster" position, in front of a fan on the nose of the crankshaft, but the frontal appearance is expected to be revised before production commences.

The weight of the vehicle has now increased to 7 tons 11 cwt, which is still less than the existing single-deck coaches. Seats for fifty-five passengers are provided.

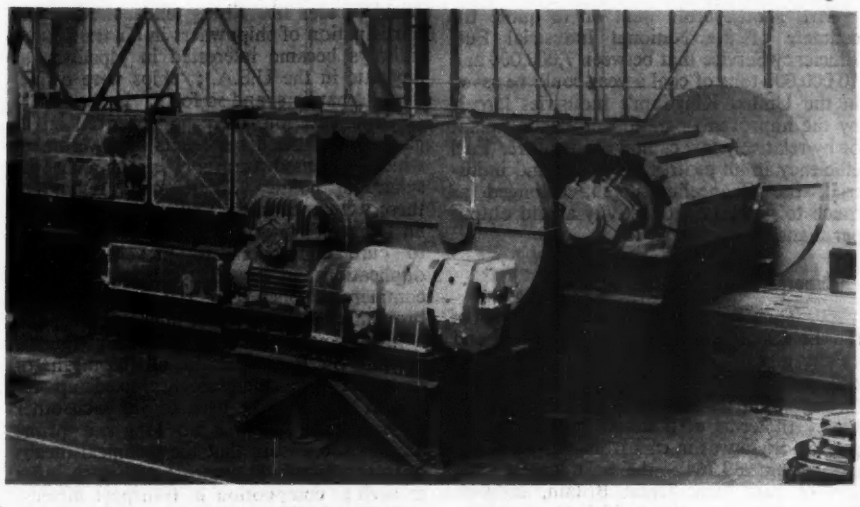
Heavy-Duty Pan Feeder for Rock Crushing Plant

A HEAVY-DUTY pan feeder built at the Fraser and Chalmers Engineering Works of The General Electric Company, Ltd., and in operation at the new cement works of the Associated Portland Cement Manufacturers, Ltd., at Cauldon Low, near Stoke-on-Trent, incorporates a system of shock absorbers. This feeder is used for conveying hard limestone rock to a primary gyratory crusher at a feed rate which can be varied to suit the rate of delivery to the plant. The system of shock absorbers has been incorporated in its design to enable the feeder to resist the impact of lumps of rock up to 3ft in size and 2 tons in weight rolling down on to its pans from tipping trucks some 12ft to 15ft above. The trucks deliver the rock into an open hopper, which provides a sloping bed of rock.

Primary reduction of the rock is carried out in a 42in "Symons" gyratory crusher, and this is followed by a secondary reduction in a 5½ft "Symons" cone crusher with screening equipment. The plant has a capacity of 250 tons of rock per hour, but the pan feeder and gyratory crusher are capable of taking double this tonnage, and provision has been made for the installation of a second cone crusher, which will double the throughput.

The pan feeder, which can be seen in the accompanying illustration, is 6ft in width (5ft 6in between skirt plates) and 19ft long from head to tailshaft centres. In the initial installation its capacity is adjustable by means of a variable-speed motor of 30 h.p. within the limits of 100 and 300 tons per hour by regulation of the speed of the pans from 2½ft to 7½ft per minute. The motor is connected to a worm reducing gear through a dry plate clutch, which is designed to slip in conditions of excessive load. From the worm gear the drive is taken to the head sprockets through a set of spur gears. A second set of gears has been provided which will enable the speed to be doubled in order to increase the capacity of the plant to 450 tons per hour.

The manganese steel pans are ribbed on the underside and have flanged sides, their mean thickness being 1¼in. They rest on three lines of special roller chains, to which they are secured by oval-headed countersunk bolts. The loaded upper lines of chains run on steel joists fitted with renewable rails, each of which is mounted on fifteen circular rubber shock absorbers enclosed in telescopic steel tubes. In addition, two skid-bars are mounted on joists directly under the pans, each bar being fitted with fourteen similar shock absorbers. These bars are not in contact with the pans under normal running conditions, but come into effect under heavy impact loads. The shock absorbers under the skid-bars are pre-stressed to reduce the initial deflection and an extra large size is fitted at the feed end, where the impact is likely to be heaviest. On the return side each chain is carried on five pairs of steel rollers.



Heavy-duty pan feeder with a system of shock absorbers

Industrial and Labour Notes

T.U.C. Award in Shipyard Dispute

At the end of last week, the disputes committee of the Trades Union Congress announced its findings concerning the recent strike at the Clyde shipbuilding yard of Alexander Stephen and Sons, Ltd. The dispute involved members of the Ship Constructors and Shipwrights' Association and of the United Society of Boilermakers ; it related to prefabrication work.

Under an agreement made between the management and both unions in 1948, steel construction work at the berths is shared by men from both unions, but the greater part of the prefabricated work has been done by members of the boilermakers' society. The amount of prefabrication at this particular yard has increased considerably in the last year or so, but the boilermakers objected to the shipwrights doing more of it. The T.U.C. committee's verdict on the matter is that the present deployment of labour is a natural consequence of the 1948 agreement, and that the stoppage of work by the shipwrights constituted a breach of the agreement. Nevertheless, the committee added, if it was feared that the company's expansion plans would mean a further reduction in the number of shipwrights at the berths, there was justification for a revision of the 1948 agreement.

Fuel Efficiency

In a speech at the silver jubilee convention of the Coal Utilisation Council, on Monday, the Chancellor of the Exchequer, Mr. Peter Thorneycroft, urged that there should be greater efficiency in the use of fuel in order to reduce the country's dependence on coal imports. The Chancellor recalled that in 1938, the country's coal output was 227 million tons, and home fuel consumption was the equivalent of 189 million tons. Coal exports in 1938 earned over £40,000,000 of foreign currency. Last year, he continued, coal production was 222 million tons and inland consumption was 254 million tons. Burning coal, the Chancellor added, was burning money and not just in our own currency. In 1953, this country spent £4,000,000 on coal imports ; in 1954, imports were £17,000,000, and in 1955 that figure increased to £74,000,000 ; there were, however, some signs of repentance last year, the Chancellor said, when the import value fell to £43,000,000.

Mr. Thorneycroft went on to quote the estimate of the National Industrial Fuel Efficiency Service that between 7,000,000 and 10,000,000 tons of coal a year could be saved in the United Kingdom's industries largely by the improved operation of existing plant or by relatively low capital expenditure. Fuel efficiency in all centres, domestic and industrial, the Chancellor urged, belonged as much to national productivity as did output per manshift.

Exports of Motor-Cars

The *Monthly Statistical Review* of the Society of Motor Manufacturers and Traders, Ltd., for October, includes an analysis of the exports of the principal producing countries for the first six months of 1957. In terms of numbers of vehicles the greatest trade was in cars from W. Germany, numbering 239,764 ; the next largest total was of cars from Great Britain, 204,946. The markets for cars in which German products predominated were as follows (purchases from this country in parentheses) :—Austria, 17,406 (2760) ; Belgium, 23,218 (10,170) ; Denmark, 8466 (4616) ; France, 2555 (1477) ; Greece, 1318 (248) ; Italy, 1440 (490) ; Netherlands, 11,765 (5555) ; Norway, 3494 (1502) ; Portugal, 3035 (851) ; Sweden, 34,361 (13,286) ; Switzerland, 17,232 (2277) ; United Kingdom, 4886 ; United States, 48,828 (43,398) ; Argentine Republic, 2915 (230) ; Brazil, 1151 (24) ; Iran, 1907 (645) ; Kenya, 1347 (1306). Countries to which Great Britain exported most cars were as follows (purchases from W. Germany in parentheses) :—Cyprus, 1008 (251) ; Irish Republic, 4102 (1049) ; Australia, 21,106 (5542); New Zealand, 15,979 (1033); Canada, 14,529 (12,851) ; British West Indies, 4319 (534) ; British Malaya, 4393 (845) ; British West Africa, 2860 (1728) ; Rhodesia, 5646 (155) ; Union of South Africa, 18,368 (9815).

Transport's Common Interest

At a meeting of the Institute of Transport, in London, last week, Sir Reginald Wilson, who is a member of the British Transport Commission, delivered his presidential address. The general theme of the address was matters concerning the outlook of the transport man.

In developing this theme, Sir Reginald made some observations on the " common interest " of transport men. The whole quality and efficiency of a transport service, he said, would often be governed, ultimately, by the nature and condition of the outlook of the men by whom it was served. Admittedly, Sir Reginald continued, there were transport men of many different kinds, but they had the same fundamental purpose. Their basic problems, whether economic like the fluctuations of load, or sociological like the need for regulation, or technological like the development of motive power, had important features in common. As the instruments of transport became more and more various, so there was the seeming paradox that it was less and less possible to regard them simply as alternative one to the other ; they became complementary to each other more and more as time went on.

Sir Reginald went on to suggest that the separatism to which the various branches of transport were once exhorted was now on the wane. In the sphere of ownership there could be seen liberalising tendencies like the participation of shipowners in air transport ; railways became interested in pipelines, at any rate in the U.S.A. ; ships were owned by road hauliers, and so forth. In the sphere of administration, there had been an amalgamation of the departments of government which regulated transport affairs. In the sphere of politics, Sir Reginald remarked, there were encountered public demands that all forms of transport should work together to cure congestion, to prevent wasteful duplication and for other purposes. In the commercial sphere, the last few years had brought continually closer inter-working, and a great development of combined transits. In sum, Sir Reginald said, all the means of transport were increasingly mixed up together, and must be used to aid each other as necessary. It was no longer a prime objective to ensure that the technical means of transport should compete with each other as such ; competition in transport increasingly depended on offering the best combination of means for any given stream of traffic. Trains conveyed the passenger's car as well as the passenger ; aircraft provided the long haul for bus traffics ; the container van might be carried by ship, railway and aircraft ; the rail truck picked up the road truck, and there might soon be seen a vehicle designed to run on both road and rail interchangeably. If we were not to have a Tower of Babel, Sir Reginald commented, the operators involved must understand one another.

Dalmuir Ordnance Factory

The Minister of Supply has announced recently that the Royal Ordnance factory at Dalmuir is being taken over by Babcock and Wilcox, Ltd. Within the last few days the company has made a statement concerning future activities at the factory. It draws attention to the fact that the world demand for power is increasing, whether it be generated from conventional or atomic fuels. In order to meet the challenge of these requirements, Babcock and Wilcox, Ltd., believes it necessary to acquire additional manufacturing facilities, and, it says, " the factory and equipment at Dalmuir provide an excellent basis for this expansion."

It will be necessary for the company in due course to augment the present facilities by additional specialised equipment to enable a greater variety of products to be made at Dalmuir. The process of taking over the factory will be gradual. Up to January 1 next, Dalmuir will continue to operate as a Royal Ordnance factory, and Babcock and Wilcox, Ltd., will be putting into the shops, on a sub-contracting basis, work suited to the available facilities. After that date the factory will be taken over fully by the firm, but during the period of transition every endeavour will be made to maintain an even load on the factory by feeding in new work as defence contracts taper off. The company is anxious to retain as far as possible the existing work force and administrative staff at present employed at Dalmuir.

Fuel Research Station at Stevenage

The Department of Scientific and Industrial Research has announced a decision to build a new fuel research station at Stevenage, Hertfordshire. It will replace the existing station at Greenwich. The decision has led to a careful review of the present requirements for fuel research, and as a consequence the programme of the new station will differ considerably from that of the old one.

Fuel research is now carried out in this country by a number of organisations and firms in addition to the Fuel Research Station. As a result of the review of the station's present programme, the projects which are to be transferred from Greenwich to Stevenage are : the study of the synthesis of carbon monoxide and hydrogen to produce oils and chemicals, and work on atmospheric pollution and its prevention, where it is planned to provide a fuller scientific service in this field for the Ministry of Housing and Local Government. The station at Stevenage will also be available to carry out any other investigations in the field of fuel research which the national interest may require and which are not more appropriately carried out by other research organisations. The estimated cost of the Stevenage station, including the site, is of the order of £750,000. Site work has already been started and it is hoped to begin occupation of the station in the autumn of 1958.

Underground Gas Storage at Beynes

While underground storage of natural gas in exhausted wells is widely practised in the United States, the use of artificial underground reservoirs is still very new. Last year, Gaz de France decided to construct a 300 million cubic metre reservoir for coke oven gas at Beynes, near Paris, in order to obtain seasonal storage. The work was carried out at great speed, and trial fillings began this spring. It is hoped to have the reservoir in partial operation this winter.

THE discovery that it is possible to store gas under pressure in exhausted natural gas wells has led in the United States to a large number of such wells being converted for this purpose. At over 180 sites natural gas is being pumped in during periods of excess production, and can then be withdrawn at times of peak demand. The practice is being taken up in Europe, and there is stated to be one such storage scheme in operation in Poland.

In a similar fashion certain dome-shaped water-bearing geological structures can be developed into artificial reservoirs, but by contrast with former sites of natural gas, gas tightness and other technical aspects are not known beforehand and must be established by special investigation. The idea is being applied in the United States, where there is one storage site near Chicago, and also in Germany at Engelbostel, near Hanover, and Reitebrook, near Hamburg. In the last instance the gas to be stored is refinery gas, whereas the other reservoirs are for the storage of coke oven gas.

In France, a large reservoir for the seasonal storage of coke oven gas is under development at Beynes, near Paris. The work goes back to 1953, when the decision to build was taken by Gaz de France, and search began for a suitable site. Two situations near Paris were judged to be suitable from the geological point of view, i.e. one south of Beynes, 22km west of Versailles, and another near Pays de Bray, 80km north-west of Paris.

Because of its greater proximity to the capital, the choice eventually fell on Beynes. There, core drillings established the presence of two domed layers of greensand. The upper layer, at a depth of about 275m, was not considered available as it supplied a number of local artesian wells with drinking water. From about 300m downwards extends the second layer belonging to the Lower Cretaceous (Weald). It is about 30m thick and contains various horizontal strata of clay at irregular levels. The sand is very fine and non-conglomerate, with a total porosity of 30 to 35 per cent and a useful porosity, taking account of the water filling, of 21 to 25 per cent. Its permeability is high, so that the water drive is intense. An initial hydrostatic pressure of 38 kg per square centimetre gauge was registered at 310m depth. The sand layer is covered over with a plastic clay which has a thickness of 7m or more. Its complete gas tightness was established on control bore tests.

The main axis of the Beynes dome (Fig. 1) extends for 3·5km in a north-west/south-easterly direction. At right angles to this the dome is just under 2km wide. Total gas capacity depends on several factors, some of which are not as yet fully known, but is estimated at between 250 million and 340 million cubic metres of gas at N.T.P. This includes a 6m thick cushion of 120 million to 150 million cubic metres, which constitutes a pocket of gas entrapped under the head of the cone which cannot normally be withdrawn.

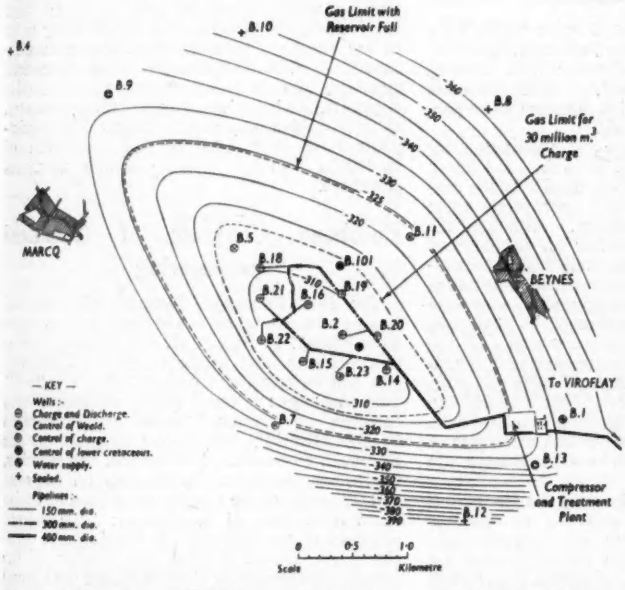
In the investigation of the Beynes structure, ten core drillings were taken down to the boundary of Tertiary and Cretaceous, and seismic tests were also carried out. As these brought no conclusive results, twelve further drillings were brought down to the Upper Jurassic, thus completely traversing the reservoir structure.

In the summer of 1955 a trial filling of 55,000 cubic metres was made by means of pressure bottles, and the gas subsequently withdrawn. These tests showed that draw-off rates of 5000 to 10,000 cubic metres per hour were possible, probably more if the reservoir were completely filled.

In order to avoid clogging and water pollution special precautions must be taken to remove from the gas which is to be stored all hydrocarbons with a tendency to polymerisation, and impurities. It was therefore decided to store at Beynes only coke oven gas which had been highly purified, with a view to its transport by high-pressure pipeline. Such gas is available from the Alfortville cokery, south-west of Paris, which is also the terminus of a coke oven gas pipeline from Eastern France. From there the gas is distributed at 20 kg per square centimetre by a ring main encircling the capital. Beynes was connected with this system by means of a feeder from Viroflay, the section between Viroflay and Alfortville being disconnected from the rest of the ring main so that it should not carry gas from any but the Alfortville works.

It is the intention eventually to equip the Beynes reservoir to supply during the winter months a daily volume of 3,000,000 cubic metres at a rate of up to 200,000 cubic metres per hour. For this purpose there will have to be fifteen to twenty gas wells grouped near the top of the dome and connected together by a collector network. Ten wells and the collector grid have already been constructed. Nearby, a station for final treatment and compression has been partially completed, its present capacity being 15,000 to 20,000 cubic metres per hour. At Viroflay a substation has been built for the distribution, decompression, recarburisation and possibly re-humidification of the gas coming from storage.

The feeder between the Viroflay substation and Beynes is 29km long and has a diameter of 400 mm. Under the working pressure of 42 kg per square centimetre the carbon dioxide contained in coke oven gas behaves in the presence of water like a strong acid. It is therefore essential to keep the pipe free of condensation. This meant that efficient separators had to be installed at the wells and at the pumping station at Beynes. To give additional protection the interior of the pipeline was treated with epicote resin paint.



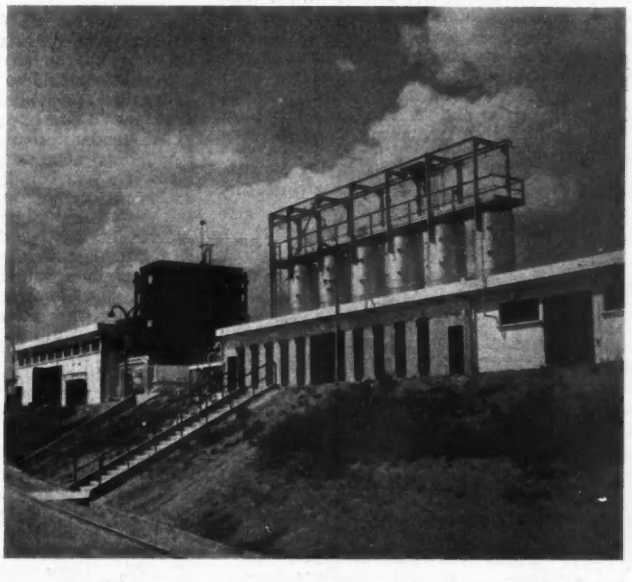


Fig. 1 (Left)—Underground storage system at Beynes, with sand layer which forms the reservoir. Fig. 2 (Right)—Gas treatment plant at Beynes showing (right to left) the gas cleaning plant with its six active carbon absorption towers, and forced draught cooling tower for the gas engines which drive the compressors, and the flowmeter building

The plant at Beynes (Fig. 2) includes compressors, filters for removing dust and oil, scrubbing plant, metering devices with automatic correction for pressure, and a final water separator in the discharge circuit. There is also a laboratory, a workshop, stores and offices, and living quarters for the staff.

The compressors consist of three "Clark" reciprocating sets driven by gas engines, with a "Fin-Fan" atmospheric cooling tower. The gas engines were originally designed for natural gas, but by increasing the inlet pressure they have been adjusted to consume coke oven gas without loss of performance. A special control device limits the delivery pressure to the reservoir to 45 kg per square centimetre by adjusting the fuel admission to the gas engines.

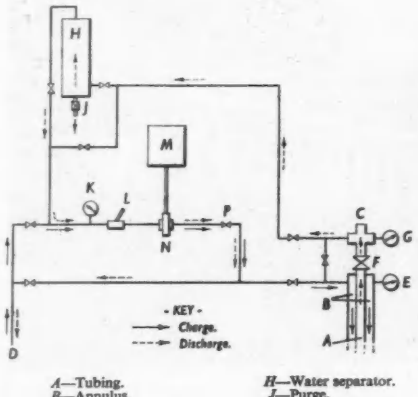
Another device allows the gas intake to the scrubbing plant to be warmed to the correct temperature in cold weather. Each compressor

set runs at 300 r.p.m. and has an output of 6000 cubic metres of free gas per hour. With a compressor inlet pressure of 16 kg or 17 kg per square centimetre and an outlet pressure of 42 kg per square centimetre gauge fuel consumption of the gas engines is of the order of 175 cubic metres per hour.

The gas scrubbing plant comprises six absorption columns filled with active charcoal and provided with circuits for purging, drying, cooling, condensation, and heating, and a cooling tower, and with means for extracting the purging gas, polluted water, and condensed hydrocarbons. In order to retain any charcoal which may be carried over from the absorption towers, ceramic filters are used to remove it. After this the rate of flow is measured. The degree of purification of the gas is stated to be unique and special control methods have had to be adopted.

It was found possible to take over four of the wells drilled for exploration purposes for charging and discharging the reservoir, so that only a further six had to be built for this purpose. Other wells are being used for control purposes or will be so used when they have been completed.

Each well has a 15in diameter guide-casing extending down for 10m or so, followed by a 9⅝in casing to a depth of 200m to 250m. The space between the bore-hole and this pipe, which measures 18in and 13in diameter in the two sections, is filled with cement grout. The bore-hole continues to full depth with a diameter of 8½in containing a 7in diameter casing, which is also grouted in. The 7in casing is taken down as far as the roof of the jurassic formation, at about 450m. The discharge tubing, which is inserted in the 7in casing, has a diameter of 2½in. At the correct depth within the greensand layer, about 315m, it terminates in a bulb with twelve perforations per metre through the bulb and lining. At soil level, the well is capped with a head containing the main discharge control valve and pressure gauge, as well as another gauge connected to the space between the 7in casing and the inner pipe, which is used for charging. Each well is equipped with a water separator for the discharging gas and a recording flowmeter through which both the incoming and outgoing gas passes (Fig. 3).



A—Tubing. *H*—Water separator.
B—Annulus. *J*—Purge.
C—Wellhead. *L*—Thermometer.
D—Collector pipe. *M*—Flowmeter.
E, G, K—Pressure gauges. *N*—Orifice plate.
F—Main shut-off valve. *P*—Control valve.

Fig. 3—Typical wellhead installation

The installation as described was completed towards the end of November last and experimental filling with 30,000,000 cubic metres of specially purified coke oven gas began in April of this year. During this procedure, one well blew up during the repair of a blocked strainer and had to be stopped with barytes mud and subsequently cemented.

Experiments to measure the individual discharge of the wells began in May. The object of these was the study of the capillary zone above the water level, the intensity of the water-drive and the water-coning, the pressure gradient inside the reservoir layer and in the wells themselves, the efficiency of the strainers, the amount of water entrained with the gas, and the chemical and physical properties of the gas.

When these tests have been completed, the charging of the reservoir is to be resumed, and during the coming winter it is hoped to be possible to withdraw gas at rates of 300,000 to 400,000 cubic metres per day.

The second stage of construction is to be carried out in the course of next summer, so that during the winter 1958-59 a daily volume of gas of 1,000,000 to 1,200,000 cubic metres should be available. From the winter 1959-60 onwards, the daily quantity will have risen to 2,500,000 cubic metres.

The capacity of the Beynes reservoir is of medium size and its shape is very flat, so that the zone of water-gas emulsion is comparatively deep compared with the total vertical displacement of the gas-water interface. There is also a single grid system for both charging and discharging. All this limits the economic and technical possibilities of operations.

Further sites are under investigation, particularly at Vernon, but also in Angoumois, Limagne, and Touraine, and in the region of Chalons-sur-Saône.

The work at Beynes was carried out under the overall direction of Gaz de France. The research, reconnaissance and study programmes were laid down by the Institut Français du Pétrole (I.F.P.), while the task of supervising the installation of equipment devolved upon the Underground Reservoir Section of the Direction des Etudes et Techniques Nouvelles (D.E.T.N.) of Gaz de France, in collaboration with other departments and organisations, in particular the Société Nationale des Pétroles du Languedoc Méditerranéen (S.N.P.L.M.).

Standardisation of German Rolling Programme

On October 1, the West German rolling mills put into operation a standard rolling programme, by which the number of rolled sizes is being reduced from 5211 to 1171, of which 1013 are envisaged as final, while 158 sizes are to be produced for the time being only.

The standard programme was agreed to a few months ago after discussions which had lasted for over a year between the rolled sections producers' association and the appropriate trade and consumers' organisations. Although the programme was based mainly on the demand during the last three years, statistical considerations were not the only ones which were taken into account. Foreseeable future demands were allowed for wherever a case could be made out, for example, with regard to heavy angles for the larger ships now under development and in connection with the manufacture of bolts and nuts. Further sections, e.g. special light sections, can be introduced into the programme at a later date.

The changes among the various categories of rolled sections due to the new programme are shown in the table below.

In general, as appeared during the discussions which preceded the new measure, the idea was well received by most firms, although, especially among smaller firms, many design changes are involved. There remain, of course, many small mills which will continue to supply non-standard sizes. Such sizes will, however, no longer come under the existing price schedules, and because of the smaller quantities involved their cost will undoubtedly increase. The Iron and Steel Section of the German Standards Institute will be responsible for seeing that the new standard rolled sizes are incorporated in all relevant draft standards.

Effect of New Rolling Programme Upon the Number of Sizes Produced

	Old	Present	Per cent reduction	Final	Temporary
Round bar	445	113*	75	113	—
Square	186	67	64	67	—
Hexagonal	166	29	82·5	29	—
Angles :					
Equal, rounded edges	380	108	71·5	92	16
Unequal, rounded edges	348	100	71·5	73	27
Equal, sharp edges	49	11	77·5	11	—
Tee-sections :					
Long, rounded	39	14	64	14	—
Broad, rounded	11	5	54·5	5	—
Long, sharp	25	5	80	5	—
Channels	18	8	55·6	8	—
Flats	3544	711	80	596	115
Total	5211	1171	—	1013	158

* Plus 51 sizes for screws and bolts.

"Univac Europe" Computer Centre

On October 19 of last year, the "Univac Europe" computing centre in Frankfurt/Main came into service. We described this installation, which is by Remington-Rand, in our issue of November 2, 1956, page 634. During the course of the first year of operation no major additions to the equipment had to be made, but a magnetic tape verifier is scheduled to be installed shortly.

Besides data on magnetic tape, the "Univac" can use eighty or ninety-digit punched cards. Problems are dealt with on behalf of firms and organisations from all over Europe; the main fields of application are industrial management, technology, applied mathematics, and public administration. For industrial undertakings the Centre has carried out inventories, statistical work, and cost and wage calculations. One task was the compiling of suitable trade names for a large firm selling branded articles. Other problems involved insurance, telephone networks, and electrical filters. Government agencies have used the Centre for statistical work, in particular in connection with agriculture. Investigations in pure mathematics have included the tabulation of circular and other functions, systems of transcendental equations, astronomy, matrices, and meteorology.

The Centre works on a shift system during five days each week, part of the night being used for maintenance. Special test programmes have been designed which are processed at regular intervals and thereby check all aspects of the machine. The work is aided by a programme library, which contains on magnetic tape records of all programmes which are likely to be of use again. This library is being constantly expanded. The staff includes a superintendent engineer, two shift supervisors, twelve service engineers, and twelve programming engineers. Over thirty-five courses with nearly 500 participants have been held for the instruction of specialists who will operate similar machines elsewhere.

European Congress of Chemical Engineering

The 1958 European Congress of Chemical Engineering will take place in Frankfurt on Main from May 31 to June 8. It will be held in conjunction with next year's ACHEMA Congress, and will include the following other congresses and meetings: the twelfth exhibition and congress of chemical engineering organised by DECHEMA; the second congress of the European Federation of Chemical Engineering, which will commence in Brussels on May 28 and 29, and will be continued at Frankfurt on Main from May 31 to June 8; the second congress of the European Federation of Corrosion; the special meeting and lectures of the Gesellschaft Deutscher Chemiker, and the annual meeting, 1958, of DECHEMA Deutsche Gesellschaft für chemisches Apparatewesen.

Information may be obtained from DECHEMA Deutsche Gesellschaft für chemisches Apparatewesen E.V., Dechema-Haus, Frankfurt/Main, Rheingau-Allee, 25.

The American Scene

BY OUR AMERICAN EDITOR

American Reactions to "Sputnik"

As man's first artificial satellite continues to circle the earth, American scientists and engineers are generally agreed that their Russian colleagues deserve great credit for a technological achievement that will go down in history as the beginning of a new era in the conquest of space. They are also generally agreed that the successful placing of a satellite weighing as much as 184 lb in an orbit as high as 560 miles must be taken as definite proof that Soviet rocket technology has reached a high stage of development. And there is general agreement that the achievement marks a major victory for Russia on the propaganda front. Government officials in Washington have been listening anxiously to the radio signals from the satellite and to the strident Soviet claims about inter-continental ballistic missiles. Washington was not disturbed so much by the piece of Soviet "hardware" flying overhead or the fact that the Soviet Union had bested the United States to place the first earth satellite in space. They were more concerned over the 184 lb weight of the satellite and the fact that Soviet rocket engines had been able to hurl such a sphere about 560 miles upward into an earth-circling orbit. To American missile experts, the Soviet rocketry accomplishment contained one significant and sobering piece of evidence: that the Soviet Union apparently had a more powerful rocket booster engine than any yet developed by the United States. The evidence fitted into a growing picture of Soviet progress in missile development. While still incomplete, the picture was detailed enough to force a reappraisal of the intense race between the U.S.A. and U.S.S.R. to develop missiles that speed to the edge of space and hit targets thousands of miles away. President Eisenhower, for the first time, publicly expressed some guarded concern over Moscow's proved ability to hurl a rocket for a long distance. Neil H. McElroy, only four hours after taking over as the new American Secretary of Defence, told reporters that, in view of the Soviet missile accomplishments, the Defence Department was seriously considering speeding up the United States missile programme by removing some of the "bottlenecks." These official reactions were in marked contrast to those following the Soviet Union's announcement of August 27 that it had test-fired an inter-continental ballistic missile "a huge distance." Then, from President Eisenhower downwards, the official reaction had been that the test firing signified little, that it was a long way from one test firing to an arsenal of ballistic missiles capable of hitting a target. What changed the tenor of official thought so much in this brief period? In a word: the "sputnik"—its astonishing weight and the mocking voice that seemed to laugh at the confidence of the United States in her technological supremacy.

Does the "sputnik" then mean that the United States is well on the way to losing to Russia the race to develop inter-continental ballistic missiles? Not necessarily, in the opinion of American experts, but it certainly was a sobering warning. The I.C.B.M. is too complex a weapon for one piece of evidence, such as the satellite launching rocket, to be conclusive about the Soviet stage of rocketry development. Even if Russia has developed a more powerful booster engine, there is still the question of designing an atomic warhead that will be compact but still pack a terrific "megaton wallop." There are also the problems of aiming and of making a warhead that will not burn up on the way down. None of the evidence is yet conclusive that Russia has gone through all these demanding technological steps and now has a militarily operational ballistic missile ready to be fired by a push-button at the United States. The evidence, however, is strongly suggestive that Russia is ahead of the United States in the ballistic missile race and is perhaps further ahead than had been supposed before the satellite took off. Even before the space traveller, there was evidence that Russia had been firing ballistic missiles for hundreds of miles, then recently for thousands of miles. Their accuracy was unknown, but at least they were soaring at considerable speeds on their elliptical trajectories. In contrast, the United States ballistic missiles are just beginning to get off the ground. Test versions of the U.S. Army's "Jupiter" intermediate range ballistic missile have been fired for distances of 1500 miles to more than 3000 miles. The U.S. Air Force's "Thor" intermediate-range ballistic missile, after several abortive starts, has finally gone the distance. The "Atlas," the inter-continental missile of the Air Force, however, has yet to go anywhere. Twice it has been fired, only to collapse a few miles off the launching pad. On the basis of past effort, it is probably inevitable that Russia should be ahead. After World War II the Russians, with the aid of captured German rocket scientists, started immediately to develop the "futuristic" weapons. In the United States, post-war work on ballistic missiles was largely limited to theoretical feasibility studies. It was not until 1954, when it was demonstrated that a compact hydrogen bomb warhead could be built, that the United States development of ballistic missiles really began in earnest. In the ensuing years, it is believed, the United States began closing the gap on the Russians. Now the Defence Department seems determined to close the gap still further—or at least prevent it from once again being widened. The department is going to remove some of the bottlenecks that have been slowing down the testing and evaluation of the missiles. The additional expense probably will not be large. But, significantly, the department will be stepping back from a recent economy decision to remove the ballistic missile programme from an untouchable status and subject it to close economy scrutiny. The lid will be lifted on overtime for scientists and engineers to accelerate the test programme, and the services may be allowed to fire more missiles faster. The Soviet victory in the first step into space does not mean, however, that there will be any speed-up in the United States programme to launch earth satellites. As President Eisenhower took pains to stress at his recent news conference, this country's satellite programme in conjunction with the International Geophysical Year was from the start deliberately separated from the military programme so as not to interfere with the development of ballistic missiles. With many not unexpected technological difficulties and some financial restraints, the satellite programme is proceeding somewhat behind schedule. The first complete prototype of the launching rocket, but with only one of the three planned rocket engines, is to be fired any day. By this winter some miniature test spheres should be launched in the test firing programme. And by early next spring scientists hope to be ready to attempt to launch the first fully instrumented United States earth satellite.

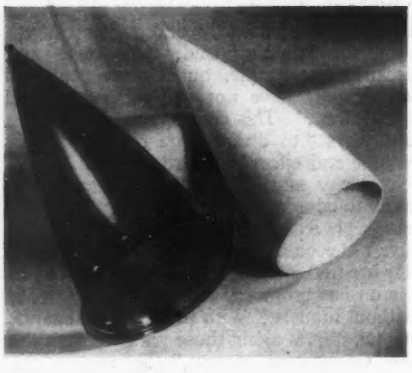
Traditionally, Americans have reacted to national emergencies by initiating "crash" programmes. Thus, one now hears demands to initiate at once a "crash" programme, similar to the wartime atomic bomb project, to catch up with the Russians and to surpass them in the shortest possible time. Whether or not it would be in the best national interests to initiate such a "crash" programme was, it may be surmised, a subject of serious discussion with President Eisenhower at his recent meeting with his top military, scientific and diplomatic advisers. But while the question "to crash or not to crash" is a major problem for military planners, it is far from being the major problem with which American scientists and educators are concerning themselves. To them the vital problem facing the nation, and the free world as a whole, is the fact that Russia is training scientists and technological personnel at a pace four times that of our own and that, unless something is done about it as a large-scale, national effort, Russia will definitely surpass the West in the near future. The problem was summed up this month at the close of the Combined College Conference by Professor John R. Dunning, Dean of the Columbia University School of Engineering. "While the Soviets have already begun their exploitation of this new and awesome age," Professor Dunning said, "we have not, because our people, our Government and our schools have not yet grasped its full significance." This country, he urged, must find ways "to divert more of the national income and effort" toward the problems of technology and technological education in order to counter the threat of a "vastly more powerful Russia." With "the power to divert the complex of national economy in any desired direction," he said, the Soviet Union has promoted its technology virtually without limits. "With the power to channel human efforts along those paths best serving the Communist system," he said, "that system has been able to produce scientists and engineers in certainly greater numbers and quite possibly of higher technical proficiency than our own." But the problem confronting American science is not solely that of training large numbers of scientists and engineers. In a free society it is not possible "to channel human efforts" without the individual's consent and wholehearted willingness. To attract able and promising young men and women into the fields of science and engineering it is necessary first to offer them better inducements than are at present offered. In this respect America is behind Russia. In Russia a scientist is not only a highly honoured member of society, he also is one of the most highly paid, the salaries of top scientists and engineers often being higher than those of important Govern-

ment officials. Furthermore, they are not stinted on funds with which to carry on their researches, as is often the case in the United States. The difference in the status of scientists in this country and in Russia is one of the basic reasons why Russia attracts more young people to the study of science than America does. In Russia the state pays for education. But in the United States the cost of a technical education has been constantly increasing, making it more and more difficult for talented young people to choose a scientific or engineering career. In addition, there is in America the difficulty of recruiting scientists for the production of weapons. For this there are several reasons. One is the danger of Congressional and other investigations of anyone in public service. Another is the reluctance of some scientists to work on weapons for reasons of conscience. Still another is the ambition of young scientists to work in more productive fields, intellectually and otherwise, rather than in the production of what they refer to as "hardware."

Crystalline Materials Made From Glass

"PYROCERAM" is the name given by the Corning Glass Works, of Corning, New York, to extremely hard, fine-grained crystalline materials formed from special glasses. A family of these new materials, covering a wide range of physical properties, is currently being developed. "Pyroceram" can be individually formulated to have good mechanical strength, good electrical insulating properties at very high frequencies, high deformation temperatures, superior thermal shock resistance, and hardness. Expansion coefficients can be varied in this crystalline material from slightly negative to 200×10^{-7} per deg. Cent.; some materials can be either transparent or opaque, and they can be made resistant to chemical attack.

"Pyroceram" is essentially a crystalline material formed from a non-crystalline glass. A glass batch containing one or more nucleating



Guided missile radomes made from "Pyroceram." The left-hand unit is transparent non-crystalline and the right-hand unit is opaque crystalline after heat treatment

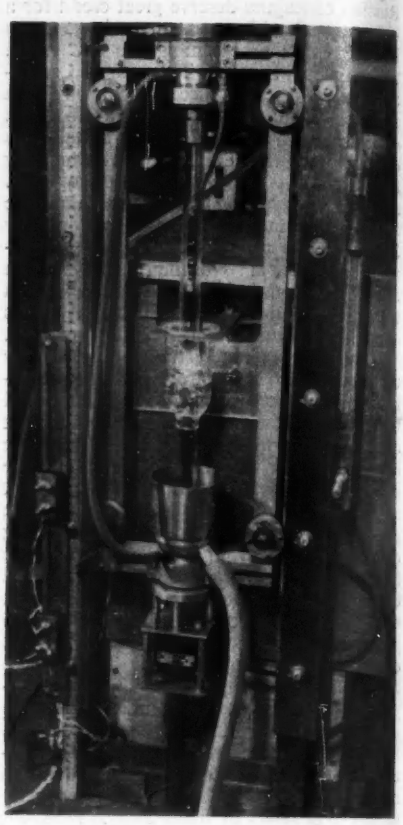
agents is melted, formed and cooled. Subsequent heat treatments cause the nucleating agents to form millions of sub-microscopic crystallites per cubic millimetre in the material, each crystallite acting as a centre of crystal growth as the heat continues. The end product, after heat treatment, is a fine-grained crystalline material, non-porous and harder than most ceramics and many metals. While more than 400 such materials have been experimentally melted, only four have been fully investigated and melted in pilot runs to date. Two of them, code numbers 8607 and 8608, are handled and formed in their glassy state in a manner similar to borosilicate glass. They can be formed by conventional glass-forming methods—blowing, drawing, pressing and rolling. The two other materials, code numbers 8605 and 8606, are very fluid at high temperatures, and can most easily be formed by centrifugal casting. Experiments indicate that these latter two materials lend themselves to forming by investment casting techniques. Pilot runs indicate that all four of these new materials are adaptable to mass production techniques.

Probably the most important characteristic of the new materials is their formability. Unlike conventional high-temperature, low-expansion ceramics, "Pyroceram" can be formed while in its glassy state into a variety of shapes and sizes by all the known glass-forming techniques. It is believed that the material can be fabricated by any of the forming processes of blowing, pressing and drawing. The special codes 8605 and 8606, which are very fluid in their glassy state, readily lend themselves also to such special forming techniques as centrifugal and investment casting. Conical shapes over 1ft in diameter and approximately 3ft long have been centrifugally cast. Experimental work is being done also in casting "Pyroceram" by lost-wax investment casting techniques. Since the size, density and chemical composition of its crystals can be controlled, the properties of "Pyroceram" can be tailored to meet specific requirements. Possessing a high ratio of strength to weight, code 8605 has a specific gravity of 2·62 and a modulus of rupture of 37,000 lb per square inch. There is very little loss of strength at temperatures up to 700 deg. Cent. Deformation temperatures range up to 1350 deg. Cent. The strength of "Pyroceram" remains relatively unaffected by surface scratches. Although the hardness of code 8605 cannot be measured by the Brinell or Rockwell machines, in comparative diamond indentation tests it has been found to be harder than flint, granite or hardened high carbon steel but not as hard as sapphire. The alignment and hardness of the crystals in this material make it extremely resistant to abrasion.

Electrical measurements made on code 8605 indicate that this material has high-frequency insulating dielectric properties comparable to those of the best electrical ceramics. At a frequency of 10^{10} c/s, the loss factor of code 8605 is 0·0022 at room temperature and 0·013 at 500 deg. Cent. In both cases this is only two thirds that of dense alumina at the same frequency. The electrical stability of the material at high temperatures and high frequencies is excellent. The dielectric constant at 10,000 Mc/s and 800 deg. Cent. has only a 0·3 per cent change from room temperature. Long-term tests on resistance to chemical corrosion of "Pyroceram" are not yet completed. Preliminary indications show codes 8607 and 8608 to be nearly as resistant to acid attack as "Pyrex" borosilicate glass. They are more resistant to alkali attack than this glass. Laboratory samples of other compositions have been made showing chemical stability to be nearly as good as that of borosilicate glass. By properly controlling the heat treatment, code 8607 may be made transparent in its crystalline form. Code 8608 may be a translucent opal or, upon further firing, a pure white opaque material. Codes 8605 and 8606 are white opaque in their crystalline form.

Automatic Floating-Zone Refining

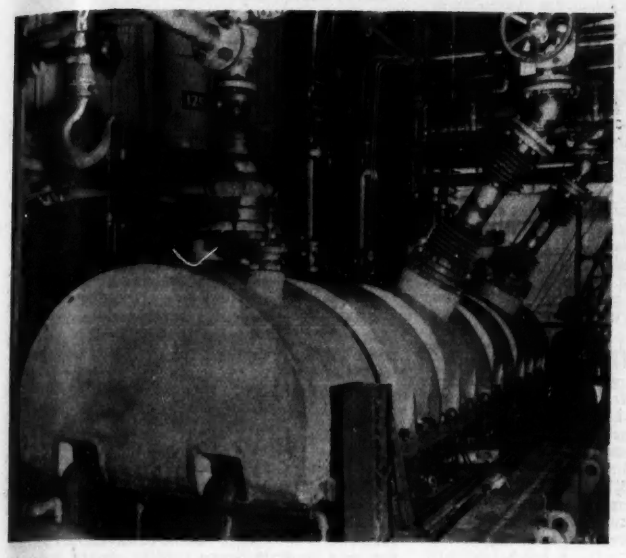
AN automatic refining device which will reduce electrically active impurities in silicon to less than 1 part in 1000 million, has been developed by the Bell Telephone Laboratories, of New York. It utilises the floating zone refining technique, in which a molten zone is swept through the silicon, carrying impurities with it. The method can also be used to purify germanium, molybdenum, tungsten and other materials. The new automatic apparatus developed at the Bell Laboratories, and illustrated here, consists of a 10kW, 4 Mc/s generator, mechanical means for moving the rod up and down while it is rotating inside a gastight silica enclosure, and switching means for automatically recycling the mechanism. Initially, because of its high resistivity, the end of the silicon rod must be heated to about 800 deg. Cent. by conduction from a molybdenum chuck, which is heated by the radio-frequency generator. Power is then absorbed by the rod itself, and all subsequent operations are automatic. The power is increased to a preset location, and the motor drives for the mechanism are started. These drives rotate the rod and move it downward, so that the molten zone traverses the rotating rod from bottom to top. When the zone reaches the top of the rod, a limit switch stops the rotation and decreases the power to a preset value sufficient to keep the heated but now solidified zone at about 1200 deg. Cent. This heated zone is then returned to its previous position near the bottom of the rod as



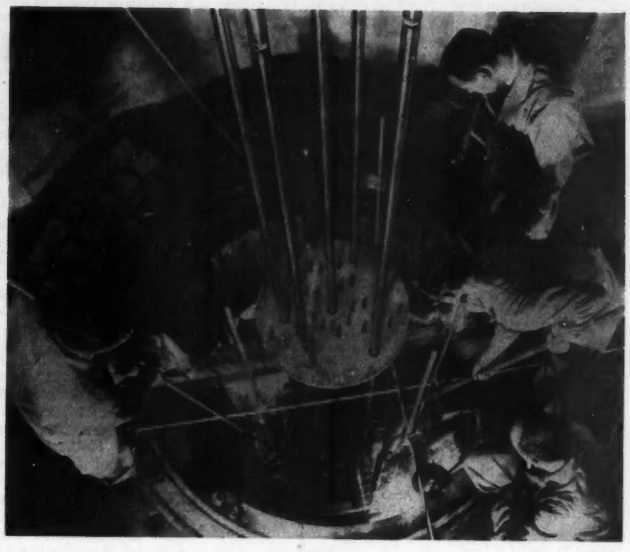
Automatic floating-zone apparatus being used to refine a silicon crystal at the Bell Telephone Laboratories

the rod is raised by the drive mechanism. There a limit switch raises the power to the preset value for melting, starts the rod rotating, and reverses its direction of travel. The automatic recycling then continues as long as required.

Constant length and freedom from mechanical oscillation of the molten zone have been achieved by employing low heating current at a relatively high frequency, and by properly proportioning the load and generator impedances. The low currents minimise the electromagnetic levitation forces, the high frequency increases the power transfer efficiency, and a ratio of load to generator impedance of less than unity stabilises the zone length. The load impedance decreases as the rod melts, so that, as the zone tends to lengthen, less power is put into the load and the temperature drops, thus tending to decrease the zone length. Crystals of uniform diameter are secured by a control of the ratio of zone length to rod diameter so that the upward transport of material by the molten zone is balanced by the gravitational force in opposite direction. By the use of this equipment with a moist hydrogen atmosphere to remove boron, a single crystal of *p*-type silicon with a resistivity of 16,000 ohm per centimetre and a minority carrier lifetime of 1200 microseconds has been obtained after sixty-seven passes. This condition corresponds to an impurity content of less than 1 part per 1000 million, and is thought to be the purest silicon ever produced in quantity.



Continuous calcining furnace for the production of uranium oxide at the Hanford Works



Loading of fuel elements into the core of the General Electric boiling water power reactor at the Vallecitos Atomic Laboratory

Uranium Oxide Production at Hanford Works

An automatic furnace installation at the Hanford Works of the U.S. Atomic Energy Commission, near Richland, Washington, is now accelerating the production of uranium oxide. The furnaces (one of which is illustrated here) are calciners, which are replacing old batch kettles in the production of UO_3. Molten uranium salt is fed into the calciners, and extremely high temperatures created by electric heating elements bake the salt and reduce it to UO_3.

The recovery of valuable unfissioned uranium from dissolved irradiated fuel elements is an important process at Hanford. The reclaimed uranium is processed and can be refined into metal for nuclear reactors, or into chemicals for gaseous diffusion plants. Until the calciners were perfected molten uranium salt was boiled in kettles or pots. Heat was supplied by electricity or propane gas and the molten salt was allowed to decompose into UO_3. When a batch was completed, the furnace was shut down to permit the manual unloading of the oxide. The furnace frequently had to be cleaned.

The new calciner furnace is never down for unloading operations. The oxide is discharged continually through a hopper while fresh molten salt pouring in from above maintains a constant balance in the oven. High-temperature acidic gases escape through special filtered exhaust pipes, and no one is exposed to radiation or radioactive contamination. Agitator paddles constantly stir up the mixture and prevent it from crusting on the sides of the oven. The new equipment is expected to eliminate shut-down time while increasing the production of uranium oxide.

Neutron Physics Section Established at N.B.S.

A Neutron Physics Section was recently established in the Atomic and Radiation Physics Division of the National Bureau of Standards, Washington, D.C. Under Randall S. Caswell as its chief, the section will be responsible for the design, development, maintenance and calibration of neutron standards, and for the calibration and certification of neutron sources. In carrying out these responsibilities, the section will undertake research on the properties and characteristics of neutrons, make studies on neutron shielding and dosimetry, and engage in the development of new or improved techniques and instrumentation for neutron detection and measurement. Research on neutron properties and characteristics will include investigations of neutron spectra, elastic and inelastic scattering cross sections, attenuation and the like. This programme includes some of the activities of the former Neutron Measurement Section.

The neutron is the key particle in the production of nuclear energy by uranium fission. The rapid growth of the nuclear energy industry has led to a need for accurate measurements of the intense neutron radiation that accompanied reactor operation. Such measurements are used in the control and operation of nuclear reactors and the protection of persons who work near all kinds of neutron sources. Expanding nuclear energy facilities have also stimulated a need for improved understanding of the interaction of neutrons with matter. This is required for the more efficient design both of nuclear reactors themselves and of the protective shielding around them. In addition, because of its lack of electrical charge, the neutron is in wide use as a tool for the study of the unsolved problems of nuclear forces and the structure of the nucleus.

Neutrons for this research at the N.B.S. are provided by nuclear reactions produced with a 2MeV Van de Graaff accelerator and by a variety of radioactive neutron sources. Most neutron sources produce simultaneously neutrons of a wide range of energies. However, certain of the reactions using the Van de Graaff accelerator have the great advantage that the neutrons produced are of only one energy. These neutrons can be used, for example, to learn how the response of a neutron detector changes with energy or to study the penetration of neutrons as a function of energy.

The Bureau maintains two kinds of neutron standards. In the first kind are standard radioactive neutron sources. Sources sent by universities, Government laboratories and industrial firms to the N.B.S. for calibration as laboratory standards are calibrated against the N.B.S. standard sources by means of the activation of a manganese sulphate bath or by relative thermal neutron flux measurements in a standard graphite pile. The second kind includes standards of thermal neutron flux in neutrons per square centimetre per second. An unknown thermal neutron flux, in a nuclear reactor, for example, may be calibrated by the activation of gold foils in the unknown flux and in the N.B.S. flux. One of the chief interests of the Neutron Physics Section is in simple, fundamental experiments on the penetration of neutrons through matter. These experiments, using mono-energetic neutron sources in simple geometries, are used to test theoretical calculations of neutron shielding. These theories are then used in the design of neutron shielding and of nuclear reactor cores. An example of this kind of work is the main problem in the design of a nuclear-powered aircraft—the weight of the radiation shield.

The interaction of neutrons with individual nuclei is described in terms of neutron cross sections which are measures of the probabilities of certain neutron interactions. Determination of cross sections is important both for the understanding of the nucleus and for the prediction of neutron behaviour in many practical problems. The present programme is directed toward the study of neutron scattering cross sections through millimicrosecond time-of-flight techniques.

Neutrons are in general more difficult to detect than charged particles and photons. The Neutron Physics Section is studying the problems of neutron dosimetry and of fast neutron spectroscopy. The need for neutron dosimetry was tragically demonstrated several years ago when a number of cyclotron workers in the United States and Europe developed cataracts from over-exposure to fast neutrons.

Boiling Water Power Reactor at Vallecitos

The developmental boiling water power reactor completed recently by the General Electric Company at the Vallecitos Atomic Laboratory, in California, has sustained its first nuclear chain reaction. The reactor achieved criticality during low-power experiments held to determine nuclear characteristics of the reactor core. However, steam for the production of electricity was not produced during the initial reactor experiments.

The reactor is one of the major nuclear research facilities of the Vallecitos Atomic Laboratory. It is designed as a prototype and will be used primarily to test the designs of the 180MW boiling water reactor being built by General Electric for the Commonwealth Edison Company of Chicago, and the Nuclear Power Group, Incorporated. When operating as a power reactor, the Vallecitos pile will supply steam for the generation of this country's first privately financed atomic electric power. This steam will be supplied to a 5MW turbo-generator installation owned and operated by the Pacific Gas and Electric Company. Electricity produced by the plant will be fed into the grid transmission lines for use in the San Francisco bay area.

Award of Timoshenko Medal.—The American Society of Mechanical Engineers has announced that the first recipient of a new award, to be known as the Timenshenko Medal, will be the man for whom it was named, Professor Stephen P. Timoshenko, formerly of Stanford University. Professor Timoshenko is cited as a distinguished member of the engineering profession and is credited with "outstanding contributions to the field of applied mechanics." The medal will be presented during the A.S.M.E. annual meeting in New York City on December 4.

Personal and Business

Appointments

MR. ARTHUR WADDINGTON has been appointed an executive director of Universal Metal Products, Ltd.

MR. J. CROSS, A.M.I.Mech.E., has been appointed director and general manager of Richard Sutcliffe, Ltd.

MR. F. C. J. BAGNALL, manager of the London branch of Redpath, Brown and Co., Ltd., has been appointed a director.

MR. JOHN W. DANKS has been appointed general manager of F. W. Magowan and Son, Ltd., in succession to Mr. T. Shelley.

MR. C. B. WRIGHT has been appointed to succeed Mr. L. W. H. Ashton as technical sales manager of Davy and United Roll Foundry, Ltd.

THE SHELL PETROLEUM COMPANY, Ltd., announces that Mr. A. S. C. Hulton, managing director of Shell Tankers, Ltd., has been appointed a director.

SCOTTS' SHIPBUILDING AND ENGINEERING COMPANY, Ltd., states that Mr. George Hilton, the shipbuilding director, has been appointed managing director.

SHORT BROTHERS AND HARLAND, Ltd., has announced that Mr. R. E. Harvey and Mr. H. G. Conway have been appointed deputy managing directors.

THE P. AND O. STEAM NAVIGATION COMPANY states that Captain C. E. Pollitt has been appointed to succeed Captain E. R. Bodley as commodore of the fleet.

LONDON TRANSPORT has announced the appointment of Mr. J. W. Denford as principal accounts assistant (accounts), with the rank of principal executive assistant.

REMINGTON RAND, Ltd., has announced the appointment of Mr. R. Hooker as public relations officer. Mr. J. Laughton has been appointed assistant public relations officer.

THE INSTITUTION OF METALLURGISTS announces that Dr. A. D. Merriman, registrar-secretary, will retire on December 31. He will be succeeded on January 1 by Mr. R. G. S. Ludlam.

THE BRITISH INTERNAL COMBUSTION ENGINE MANUFACTURERS' ASSOCIATION has announced that Mr. Anthony Vivian Wilkin has been elected chairman of the council, and Mr. Leonard Pelham vice-chairman.

MR. K. J. CLARKE has been appointed to succeed Mr. C. A. Russell as manager of the British Thomson-Houston Company, Ltd., district office, Sheffield. Mr. Russell has retired after forty-five years' service with the company.

DR. A. E. LAURENCE has been appointed manager of the European office, central research department, of the Minnesota Mining and Manufacturing Company, St. Paul, U.S.A. His address is 3M House, Wigmore Street, London, W.1.

THE BRITISH ENGINEERS' ASSOCIATION states that Sir Edward Thompson, J.P., has been elected president, and Mr. A. I. Baker, M.I.Mech.E., vice-president, and the retiring president, Mr. W. K. G. Allen, M.I.Mar.E., has been elected honorary treasurer.

SIR ANDREW MCCANCE, F.R.S., chairman and managing director of Colvilles, Ltd., has been invited to continue as president of the British Iron and Steel Federation for 1958. Mr. Lewis Chapman, chairman of William Jessop and Sons, Ltd., has been appointed president-elect.

REAR ADMIRAL SIR MATTHEW SLATTERY, chairman and managing director of Short Brothers and Harland, Ltd., has been appointed a director of the Bristol Aeroplane Company, Ltd., and chairman of Bristol Aircraft, Ltd., in succession to Mr. C. F. Uwins, who has been appointed a deputy chairman of the parent company.

THE MINISTRY OF TRANSPORT AND CIVIL AVIATION has announced that Mr. F. J. Welch, M.I.Mar.E., engineer surveyor-in-chief in the consultative branch is to retire on December 20. He will be succeeded by Mr. G. Burdon, deputy engineer surveyor-in-chief, who will in turn be succeeded by Mr. W. Young, M.I.Mar.E., M.I.N.A.

IGRANIC ELECTRIC COMPANY, Ltd., announces that Mr. J. Russell Taylor, M.I.E.E., M.I.Mech.E., director of development and research, will relinquish his departmental responsibilities as from January 1, 1958, to become consultant to the managing director and management generally on all matters connected with development, research and production. Mr. G. B. Harrold will become chief development engineer.

MR. D. F. W. MCNAIR has been appointed general manager of a new division created by F. Perkins, Ltd., to develop and introduce certain new products into the organisation. He has been succeeded as export sales manager by Mr. J. M. Collins, who will also be responsible for the administration of overseas companies and overseas manufacture. Mr. D. McSweeney has been appointed to succeed Mr. Collins as general manager of Perkins Diesel (Overseas) Pty., Ltd., Dandenong, F. Perkins, Ltd.'s, Australian subsidiary. Mr. G. E. Smith has been appointed deputy general manager of the new products division.

SAMUEL FOX AND CO., Ltd., a subsidiary of the United Steel Companies, Ltd., announces that Mr. D. N. Riley has been appointed manager of its Rothersfield works, and Mr. E. E. Beard has been appointed manager of the laminated and coil spring departments. Mr. A. Aspinall is to be transferred from the Rothersfield works to become assistant manager of the laminated and coil spring departments at Stocksbridge, and Mr. E. Hampshire technical superintendent, spring manufacture, is to be given certain additional technical and liaison duties in connection with the umbrella department.

THE BRITISH INTERNAL COMBUSTION ENGINE RESEARCH ASSOCIATION has announced that Viscount Falmouth has been re-elected president, and Sir Harold Roxbee Cox and Professor O. A. Saunders have been re-elected vice-presidents. Vice-Admiral N. E. Dalton, Mr. H. N. Pemberton and Brigadier S. A. Stewart have also been elected vice-presidents. Mr. B. D. Giordan and Mr. C. G. Tangye have been elected to the council in succession to Mr. J. Calderwood and Mr. V. H. Hopkins. Mr. A. C. Yeates has succeeded Mr. G. W. Bone as chairman of the council and Mr. Giordan has been elected vice-chairman.

Business Announcements

MR. JOHN ASHCROFT, naval architect and a technical director of Henry Robb, Ltd., Leith, since 1935, has retired.

MR. D. K. FRASER, managing director of Petters, Ltd., Staines, has left London for a visit to America and Canada.

DAVID ROWAN AND CO., Ltd., 231, Elliot Street, Glasgow, states that it is to manufacture under licence the G.S. 34 free piston gasifier.

UNILEVER, Ltd., states that Mr. C. T. Gould, M.I.E.E., has relinquished his appointment as head of the production study department.

BRITISH RAILWAYS, LONDON MIDLAND REGION, states that Mr. H. H. Matthews has retired from his post as architect (London Midland Region) after forty-five years' service.

COLOUR SPRAYS, Ltd., has announced that its works and offices will be removed to Albion Works, North Road, London, N.7 (telephone, North 6091), with effect from November 1.

THE KEY ENGINEERING COMPANY, Ltd., states that with effect from November 2, the company's address will be Larkfield, Nr. Maidstone, Kent (telephone, Maidstone 7461 and 7233).

DENHAM'S ENGINEERING COMPANY, Ltd., Halifax, states that it has appointed Henderson and Keay, Ltd., 189, Pitt Street, Glasgow, C.2, as its sole sales representative for Scotland.

PLOWRIGHT BROTHERS, Ltd., Chesterfield, has established a London sales office at 40, Broadway, S.W.1 (telephone, Trafalgar 2104), under the administration of Mr. C. A. Kershaw.

THE STAVELEY IRON AND CHEMICAL COMPANY, Ltd., has opened an office and stockyard for the south-western area at Denver Road, Topsham, Nr. Exeter (telephone, Topsham 4123).

MR. SEBASTIAN DE FERRANTI, director of Ferranti, Ltd., has left by air for a month's tour of the company's interests in the electrical manufacturing industry in Canada and the United States.

BIRWELCO, Ltd., Chester Street, Aston, Birmingham, states that it has formed a new company, Petrochem G.m.b.H., to manufacture " Iso-Flow " fluid heating furnaces to the design of Petro-Chem Development Company, Inc., of New York. This new company, which will be entirely independent, with German staff, will also market, erect and service these furnaces.

SOUTHERN AREAS ELECTRIC CORPORATION states that New Day Electrical Accessories, Ltd., production unit, has been transferred from Birmingham to Chalford, Gloucester, and the company has been completely integrated with New Day Electric, Ltd., which was formerly titled Gillott Electro Appliances, Ltd. New Day Electric, Ltd., will, under the new arrangements, manufacture the existing range of space, convector, and immersion heaters, and the " Newday " range of electrical accessories, switches and plugs. The Southern Areas Electric Corporation also announces that, consequent upon the rationalisation of production referred to, New Day Electrical Accessories, Ltd., has been placed into voluntary liquidation.

Contracts

THE BOLTON STEAM SHIPPING COMPANY, Ltd., has placed a contract with Smith's Dock Company, Ltd., for a general cargo ship of 12,500 tons deadweight, fitted with free piston gas turbine machinery. This will consist of four G.S. 34 free piston gas generators, supplying a 4000 s.h.p. double-reduction gas turbine, having a separate astern turbine, designed for gas conditions of 44 lb per square inch gauge and 833 deg. Fah.

SCOTTISH AVIATION, Ltd., is to supply to Philippine Airlines five " Twin Pioneer " aircraft with Pratt and Whitney R.1340 " Wasp " S.I.H.1-G engines. These engines, like the normal Alvis " Leonides," are nine-cylinder radials with single-speed superchargers; instead of 540 h.p. for take-off they give 600 h.p. and 550 h.p. m.e.t.o. Hamilton standard propellers will be used. A normal " Twin Pioneer " will be supplied in December for crew training and route evaluation.

HEAD WRIGHTSON PROCESSES, Ltd., has contracted with Land-Nordrhein-Westfalen, Germany, to co-operate in the design and engineering of a nuclear reactor for research. The latter is to be a high-flux material testing reactor, we learn, similar to DIDO at Harwell and HIFAR in Sydney, Australia, both of which were also products of Head Wrightson. The new reactor is intended for the Land atomic research establishment, and is to be at the disposal of Aachen, Bonn, Cologne and Münster Universities. The U.K. Atomic Energy Authority will supply the enriched uranium fuel elements.

Miscellanea

EXHIBITION OF DRAWING-OFFICE EQUIPMENT.—An exhibition of drawing-office and photocopying equipment is to be held by Hall Harding, Ltd., of Stourton House, Dacre Street, London, S.W.1, at the Mechanics Institution, Trinity Square, Nottingham, from October 30 till November 5. This exhibition, which will be open daily from 9.30 a.m. to 6 p.m., will include examples from the firm's range of printing, developing and copying machines; drawing stands and drafting machines, and the variety of materials and instruments made for drawing and design office use.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—The report of the council, 1956-57, which was presented at the general meeting of the North East Coast Institution of Engineers and Shipbuilders, held on October 18, records a further increase in membership to a total of 2190. Fifteen papers were read during the session and that given by Dr. A. J. Johnson, and Mr. P. W. Ayling, entitled " Graphical Presentation of Hull Frequency Data and the Influence of Deckhouses on Frequency Prediction," was awarded the M. C. James Medal. The report also states the Institution Scholarship for 1957 was awarded to Mr. J. R. Oughton, and that Mr. P. Aaron was awarded the 1957 Swan, Hunter and Wigham Richardson Scholarship and Prize.

CAREERS IN AGRICULTURAL ENGINEERING.—The important part played by machinery in agriculture all over the world has led the Institution of British Agricultural Engineers to organise a " Careers in Agricultural Engineering " lecture. This lecture, which is specially designed for 'teenage schoolboys (and girls), is to be presented by Mr. W. H. Cashmore, Director of the National Institute of Agricultural Engineering, and Mr. J. E. Bywater, head of the Ford Motor Company's research division. It will be delivered on Monday, November 11, at 3 p.m., in the lecture theatre of the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2. Application for admission tickets (free of charge) should be made to the Institution of British Agricultural Engineers, 6, Buckingham Gate, London, S.W.1.

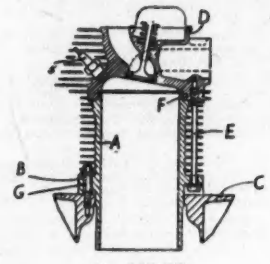
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

INTERNAL COMBUSTION ENGINES

783,562. May 6, 1955.—CYLINDERS FOR INTERNAL COMBUSTION ENGINES, Klockner-Humboldt-Deutz A.G., Deutz-Mulheimerstrasse 149/155, Koln-Deutz, Germany.

The invention relates to cylinders for internal combustion engines, with direct air cooling, and the method of attaching the separate cylinder head to the working cylinder. Referring to the drawing, the cylinder *A* for a four-stroke internal combustion engine has at its lower end an annular flange *B* for attachment to the engine housing *C*. The cylinder head *D* is attached to the cylinder by means of bolts *E*, the threaded parts of which are screwed into the



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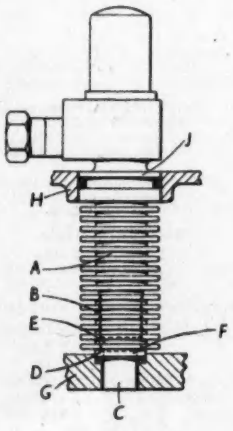
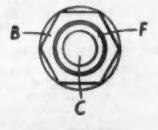
reinforced edge *F* of the cylinder head. The bolt head engages with the attachment flange *B* of the cylinder, which has a cut-away portion at this position. In addition to the cylinder head attachment bolts there are also bolts *G* for the attachment of the cylinder *D*. The small clearances of these two kinds of bolts result in low bending stresses in the flange. When the cylinder has to be removed from the engine housing it is only necessary to release the bolts *G* while the tensioning bolts *E* remain tight.—*September* 25, 1957.

783,788. November 5, 1954.—FUEL INJECTORS FOR COMPRESSION-IGNITION ENGINES, R. A. Lister and Co., Ltd., Dursley, Gloucestershire. (*Inventor: Alberto Jorge Morris.*)

The invention relates to fuel injectors particularly for use in air-cooled engines. As shown in the drawing, the body of the injector comprises a substantially tubular part *A* in which are mounted the moving parts of the injector, and a nut *B* which is threaded on the main body and secures an injector





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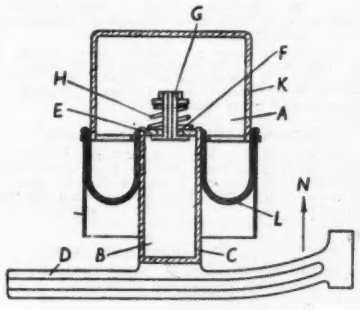
nozzle member *C* to it. For this purpose the nut is provided with an internal annular shoulder *D* which co-operates with a corresponding external annular flange *E* on the nozzle, the flange being so located that the lower portion of the nozzle protrudes below the end of the nut. The external surface of the nut is accurately machined at its lower end to afford a spigot location *F* in the cylinder head for the lower end of the injector, the lower edge of the spigot location being slightly chamfered. The cylinder head of the engine comprises an inner wall *G* and an outer wall *H* with an air space between the walls. A supply of cooling air is circulated between the two walls. The injector body is provided with a locating flange *J* and a groove machined on the flange contains a rubber ring to prevent leakage of lubricating oil into the space between the walls of the cylinder head. Peripheral cooling fins are provided on the external surfaces of the body and nut of the injector. The flow of cooling air between the inner and outer walls of the cylinder head passes over the finned portions to ensure effective cooling of the injector. In some arrangements it is found sufficient to provide cooling fins only on the nut.—*October* 2, 1957.

ROAD TRANSPORT

784,020. September 30, 1955.—PNEUMATIC SPRINGING FOR MOTOR VEHICLES, Maschinenfabrik Augsburg-Nürnberg A.G., Nürnberg, Germany.

The invention relates to pneumatic springing means for motor vehicles, comprising two air chambers intercommunicating through a throttling device which makes available a greater passage cross-sectional area during the contracting movement than during the expanding movement. The pneumatic springing means illustrated in the drawing has two air chambers *A* and *B*. The first air chamber is enclosed by a pressure container *C* connected to the wheel axle *D*. A throttling device is arranged in the cover *E* of the pressure container *C*. The cover is provided with an aperture *F* which is closable by a flange of a



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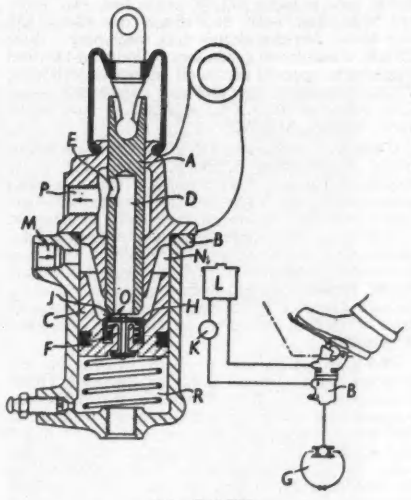
valve body *G*. This valve body passes through the aperture *F* with substantial radial clearance. The throttling device provides communication between the first air chamber *B* and the second air chamber *A*. The second air chamber *A* is enclosed by a pressure container *K* co-operating with a diaphragm *L* and is attached to the second of the two vehicle parts. When a wheel moves in the direction of the arrow *N* the valve body *G* is moved downwards against the action of the spring *H* so that air can flow relatively rapidly through the aperture *F* from the air chamber *A* into the air chamber *B*. When the wheel moves back the flange of the valve body *G* is pressed against the cover *E*, the aperture *F* is closed and compressed air can flow relatively slowly from the air chamber *B* into the air chamber *A*. The equalisation of air pressure is thereby retarded and the damping action of the shock-absorbers provided in addition to the pneumatic springing means is greatly assisted.—*October* 2, 1957.

HYDRAULIC MACHINERY

782,755. January 26, 1955.—POWER-ASSISTED HYDRAULIC BRAKING APPARATUS, Heinz Teves and Ernst August Teves, trading as Alfred Teves Maschinen-und Armaturenfabrik K.G., of 41–53, Rebstöcker Strasse, Frankfurt/Main, Germany.

According to the invention there is provided a power-assisted hydraulic braking apparatus in which a continuously circulating braking system is separated from a static hydraulic braking system by means of the master cylinder piston. A fluid pressure balance is maintained between the two systems when the apparatus is inoperative through an axial passage in the master cylinder piston, the passage being closed by the valve member in operation. In the drawing, in which the right-hand view is a diagram of the brake system and the main view an enlarged cross section of the master cylinder, a manually operable valve member in the form of a plunger *A* is displaceable by a pedal in a vertical master cylinder *B* containing the master cylinder piston *C*. The plunger *A* is provided with an axial bore *D*, which opens at a right angle into an aperture *E*. The master cylinder piston *C* is provided with an axial valve passage *F*, which connects the spaces on both sides of the piston *C* in the rest position of the piston, and allows fluid pressure balance in the static hydraulic braking system *G*. The valve passage *F* is covered adjacent the plunger *A* with a spring-loaded cap *H* provided with apertures *J*. A pump *K* draws fluid from the container *L* and pushes it through a connection *M* above the piston into the space *N* above the piston, through the passage *O* between the plunger *A* (see right-hand view), and the



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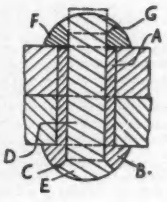
valve cap *H* into the plunger duct *D*, through the aperture *E* and the connection *P* and back into the container *L*. A preliminary pressure is produced in the space *N* by means of this circulating stream, and is transferred through the apertures *J* in the valve cap *H* and through the valve passage *F* into the space *R*, and thus to the braking system *G*. If the plunger *A* is now displaced towards the piston *C* by the foot via the pedal, the plunger duct *D* and the valve passage *F* are closed by the plunger *A* coming up against the valve cap *H*. This interrupts the hydraulic circuit so that the pump creates pressure in the space *N* above the master cylinder piston which transmits this pressure to the liquid in the static braking system to actuate the brakes. Pressure simultaneously arises on the plunger *A* and reacts on the foot. The passage *O* between the plunger *A* and the valve cap *H* must be maintained closed against this pressure, in order to achieve further displacement of the master cylinder piston *C*, and thus cause the fluid under pressure to be forced out of the space *R*. This method of operation gives rise to a pressure in the braking system *G* controllable by means of the foot.—*September* 11, 1957.

STRUCTURAL ENGINEERING

784,203. February 15, 1956.—LIGHT METAL RIVET, Aktiengesellschaft fur Unternehmungen der Eisenund Stahlindustrie, Altendorfer Strasse 103, Essen, Germany.

The rivet illustrated in the drawing comprises a hollow rivet part *A* having an integral head *B* formed with a countersunk recess *C*. A core *D* projects at both ends from the hollow rivet. The countersunk head *E* of the core fills the recess *C*, and the end of the shank of the core projects initially, to the extent indicated in chain dotted lines, beyond an annular member *F*, separate from the hollow rivet *D* and formed with a countersunk recess *G*. When the rivet is clinched, this projecting portion of the shank of the rivet core is deformed and squeezed into the recess *G* and co-operates with the annular member *F* to form the other rivet head. As an alternative, the countersunk head *E* may be positioned within the recess *G* and a projecting end of the shank of the rivet core clinched into the recess in the head *B*. Tests performed with rivets according to the invention have shown that it is possible to clinch light metal rivets of very much greater diameters than has hitherto been possible and in such manner as to obtain neat, well-formed rivet heads and complete filling of the holes in the work. The invention has accordingly made it possible to employ light metal rivets where large rivet connections are required, particularly rivet connections which must be capable of withstanding large shearing stresses.—*October* 2, 1957.



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Launches and Trial Trips

CLAN MATHESON, cargo liner; built by the Greenock Dockyard Company, Ltd., for the British and Commonwealth Shipping Company, Ltd.; length between perpendiculars 465ft, breadth moulded 65ft 6in, depth moulded to upper deck 39ft 7½in, deadweight 9760 tons on 27ft 3in mean draught; service speed 16½ knots; twelve passengers; five holds, bale capacity 572,000 cubic feet, two 3-ton, ten 5-ton, four 7-ton, two 15-ton, one 80-ton and two 40-ton derricks, electric deck machinery; three 220kW diesel-driven generators; Wallsend-Doxford diaphragm, opposed piston oil engine, six cylinders, 750mm diameter by 2500mm combined stroke, 7500 b.h.p. at 103 r.p.m., arranged to burn heavy fuel.—Launch, August 26.

CAPETAN CHIOTIS, cargo ship; built by the Burntisland Shipbuilding Company, Ltd., for Sarac Compania Naviera, S.A., Panama; length between perpendiculars 445ft 10in, breadth moulded 62ft 4½in, depth moulded to upper deck 41ft, deadweight 13,550 tons; five cargo holds, ten 10-ton derricks, electric deck machinery; three 180kW diesel-driven generators; Kincaid-B. and W. two-cycle, single-acting, pressure charged diesel engine, six cylinders, 620mm diameter by 1400mm stroke, arranged to burn heavy fuel, 5800 b.h.p. at 118 r.p.m.—Launch, August 26.

PROCYON, cargo liner; built by the Furness Shipbuilding Company, Ltd., for Sociedad Transoceanica Canopus, S.A., Panama; length between perpendiculars 480ft, breadth moulded 66ft, depth moulded to upper deck 42ft 6in, deadweight 16,200 tons on 31ft 5½in summer draught, capacity 818,500 cubic feet; five cargo holds, fifteen derricks 2 to 30 tons capacity, electric winches; three 150kW diesel-driven generators, one 50kW steam-driven generator; Hawthorn Leslie-Doxford single-acting, two-stroke, opposed piston oil engine, five cylinders, 670mm diameter by 2320mm combined stroke, 5500 b.h.p. at 115 r.p.m.—Launch, August 26.

HALIA, oil tanker; built by Hawthorn, Leslie (Shipbuilders), Ltd., for Shell Tankers, Ltd.; length overall 557ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,000 tons; thirty-three cargo oil tanks, one main cargo pump room, four vertical centrifugal turbine-driven cargo pumps; two 550kW, 450V, 60 c/s geared turbo-alternators, one 200kW diesel-driven alternator; one set of Hawthorn Leslie two-cylinder geared turbines, taking steam at 500 lb per square inch and 800 deg. Fah., from two Foster-Wheeler "D" pattern boilers, 8250 maximum s.h.p.—Launch, August 27.

KING GEORGE, cargo ship; built by Harland and Wolff, Ltd., at Belfast, for the King Line, Ltd.; length between perpendiculars 435ft, breadth moulded 59ft, depth moulded to shelter deck 39ft 9in, deadweight 9500 tons; two complete steel decks, eight watertight compartments, four main holds, one 50-ton, one 25-ton, four 10-ton, six 5-ton derricks, electric deck machinery; three 125kW diesel-driven generators; Harland-B. and W. single-acting, four-stroke diesel engine, six cylinders, 740mm diameter by 1500mm stroke, 115 r.p.m.—Launch, August 27.

Catalogues and Brochures

VERITYS, Ltd., Plume Works, Aston, Birmingham, 6.—Catalogue illustrating and describing Maxlume floodlighting equipment.

SPRAYED INSULATIONS, Ltd., 5, Fenchurch Street, London, E.C.3.—Leaflet describing "Silbestos" sprayed asbestos insulation.

LAMSON ENGINEERING COMPANY, Ltd., Hythe Road, London, N.W.10.—Leaflet describing and illustrating mobile conveyors made by this company.

RHODES, BRYDON AND YOUATT, Ltd., Waterloo Engineering Works, Gorsey Mount Street, Stockport.—Leaflet No. 1524, describing the molten metal "Mopump."

SELF-CHANGING GEARS, Ltd., Lythalls Lane, Coventry.—Booklet entitled "Railcar Progress Around the British Isles," which gives a short survey of railway progress.

MODERN WHEEL DRIVE, Ltd., 15, Dartmouth Street, London, S.W.1.—Leaflet giving details of Hindmarch/MWD epicyclic marine oil-operated reversing and reverse-reduction gears.

PLANNAIR, Ltd., Windfield House, Epsom Road, Leatherhead, Surrey.—Brochure entitled "Design for Blowing." Details are given of this company's progress in air movement, and also of their high-efficiency blowers. Various illustrations and diagrams are included of types of blowers, giving details of performance and some of the uses to which these blowers are put.

G.W.B. FURNACES, Ltd., P.O. Box 4, Dibdale Works, Dudley, Worcs.—Catalogue dealing with box type electric furnaces; it describes and illustrates furnace loading, air circulation, heating elements, heating chamber, door gear, electrical equipment, and also deals with box furnaces in the aluminium industry, describing precipitation hardening, solution heat-treatment and annealing.

WALTERISATION COMPANY, Ltd., Waddon Marsh Way, Purley Way, Croydon, Surrey.—Leaflet giving details of the Foscote series of treatments which has been designed for cold brush-on application to rusty iron and steel, aluminium or galvanised surfaces, for improved adhesion of subsequently applied paint films and increased corrosion resistance of the complete finishing sequence.

DAVEY, PAXMAN AND CO., Ltd., Colchester.—Brochure No. 1444, illustrating and describing Paxman 7in bore diesel engines for rail traction; details of dimensions and performance of a range of diesel engines are given, together with installation features, specifications, standard and optional equipment. Details are also given in diagrammatic form of the water-cooling system, fuel oil system, lubricating oil pressure system, and lubricating oil cooling system. Included at the end is an "8 RPH" diesel engine shown in "Transart" section.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Oct. 25.—COVENTRY BRANCH: Visit to the English Electric Company, Rugby Works, 8 p.m.

Tues., Oct. 29.—LONDON NATIONAL LECTURE: Institution of Electrical Engineers, Savoy Place, London, W.C.2, Presidential Address, Sir Harold Bishop, 6.30 p.m. ★ S. WALES BRANCH: Angel Hotel, Westgate Street, Cardiff, A.E.I. Lighting Demonstration and Lecture, 7.30 p.m.

Wed., Oct. 30.—GLASGOW BRANCH: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Refrigeration," B. McLaren, 8 p.m.

Fri., Nov. 1.—BRISTOL AND WEST OF ENGLAND BRANCH: Grand Hotel, Broad Street, Bristol, "The Work of the National Fire Service," 8 p.m. ★ LIVERPOOL AND DISTRICT BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, 2, "Electronic Instrumentation and Control," A. Williams, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Oct. 30.—London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Tropospheric Scatter System Evaluation," M. Telford, 6.30 p.m. ★ S. WALES SECTION: Glamorgan Technical College, Treforest, "Electroencephalography," H. W. Shipton, 6.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Thurs., Oct. 31.—N.W. REGION: Engineers' Club, Albert Square, Manchester, "Coal Mining," F. G. Glossop, 2.30 p.m. ★ MIDLAND REGION: Queen's Hotel, Birmingham, "Future Developments in Steam Generators," H. A. Cameron, 10.30 a.m., "Recent Developments in Space Heating," J. R. Kell, 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Oct. 25.—BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, "Horticultural Lighting," A. W. Gray, 6 p.m.

Mon., Oct. 28.—LEEDS CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Lighting at London Airport," J. G. Holmes, 6.15 p.m. ★ LEICESTER CENTRE: East Midlands Electricity Board, Charles Street, Leicester, "Lighting as a Basis for Design," Derek Phillips, 7 p.m.

INCORPORATED PLANT ENGINEERS

Tues., Nov. 5.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2, "Lighting Installations for Industry," W. Robinson, 7 p.m. ★ GLASGOW BRANCH: St. Enoch's Hotel, Glasgow, Brains Trust, 7.15 p.m. ★ PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Flight Testing of High Speed Aircraft," 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Wed., Oct. 30.—JUNIOR MEETING: Poplar Technical College, London, E.14, "The Construction of the Ship," G. Ridley Watson, 7 p.m.

INSTITUTE OF PETROLEUM

Wed., Nov. 6.—26, Portland Place, London, W.1, "The Impact of Cyclical Fluctuations on Fuel Oil Demand," G. Chandler and D. W. Lindsell, 5.30 p.m.

INSTITUTE OF PHYSICS

Mon., Oct. 28.—SCOTTISH BRANCH: Department of Natural Philosophy, The University, Edinburgh, "The Protection of Development and Research by Patents," H. J. Fitzpatrick, 7.15 p.m.

Tues., Oct. 29.—SCOTTISH BRANCH: Royal College of Science and Technology, Glasgow, "The Protection of Development and Research by Patents," H. J. Fitzpatrick, 7.15 p.m.

Wed., Oct. 30.—LONDON AND HOME COUNTIES BRANCH: Visit to the Laboratories of the Morgan Crucible Company, Battersea, London, S.W.11, 2 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Nov. 7.—Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "A Review of Methods for Odour Control in Refrigerated Space," W. Summer, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Nov. 4.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Use of Plastics in Road Transport," M. D. Curwen, 7.30 p.m.

Wed., Nov. 6.—E. MIDLANDS CENTRE: Mechanics Institute, Nottingham, "Taking Stock on Maintenance," P. H. Wyke-Smith, 7.30 p.m. ★ WESTERN CENTRE: Royal Hotel, Bristol, "The Manumatic Gearbox," P. J. Holman, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., Oct. 29.—N.W. BRANCH: Blossoms Hotel, Chester, "Some Aspects of the Large Scale Use of Irradiations in Industry," R. Roberts, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Nov. 5.—Great George Street, Westminster, London, S.W.1, Presidential Address, Sir Arthur Whitaker, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Oct. 25.—SOUTHERN CENTRE: South Dorset Technical College, Weymouth, "The Transatlantic Telephone Cable," R. J. Halsey, 6.30 p.m.

Mon., Oct. 28.—MERSEY AND N. WALES CENTRE: Town Hall, Chester, "Cathodic Protection," L. B. Hobgen, K. A. Spencer and P. W. Heselgrave, 6.30 p.m. ★ N.E. CENTRE: Neville Hall, Newcastle upon Tyne, "138kV Submarine Power Cable Interconnection between the Mainland of British Columbia and Vancouver Island," T. Ingledow, R. M. Fairfield, E. L. Davey, K. S. Brazier and J. N. Gibson, 6.15 p.m. ★ S. MIDLAND RADIO AND MEASUREMENTS GROUP: James Watt Memorial Institute, Great Charles Street, Birmingham, "Electronics and Automation—the Use of Nucleonic Devices," Denis Taylor, 6 p.m.

Tues., Oct. 29.—CAMBRIDGE RADIO AND TELECOMMUNICATION GROUP: Cavendish Laboratory, Free School Lane, Cambridge, "The Importance of Research in Hearing and Seeing to the Future of Telecommunication Engineering," E. C. Cherry, 8 p.m. ★ N. MIDLAND CENTRE: Central Electricity Authority, 1, Whitehall Road, Leeds, "Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and Above," A. Norris Thomas and D. F. Oakeshott, 6.30 p.m.

Wed., Oct. 30.—SHEFFIELD SUB-CENTRE: Technical College, Scunthorpe, "The Construction of the 275kV Transmission Lines," J. D. Pierce, 7 p.m.

Mon., Nov. 4.—EAST ANGLIAN SUB-CENTRE: Crown and Anchor Hotel, Ipswich, "Colour Television," L. C. Jesty, 6.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Sat., Oct. 26.—N.E. BRANCH: Visit to Huwood Mining Machinery, Ltd., Team Valley Trading Estate, 9.30 a.m.

Tues., Oct. 29.—Linden Hall Hydro, Boscombe, Hants, "Reminiscences and Present Day Reflections," Sir Alan Cobham, 7.30 p.m.

INSTITUTION OF ENGINEERS IN CHARGE

To-day, Oct. 25.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, Presidential Address, Sir Harold Roxbee Cox, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Fri., Nov. 1.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Street Lighting," Granville Berry, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Oct. 25.—GENERAL MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Dynamic Stresses in the Teeth of Spur Gears," S. L. Harris, 6 p.m.

Mon., Oct. 28.—EASTERN BRANCH: The Dujon Restaurant, Bedford, "An Investigation into the Mechanism of Oil Loss Past Pistons," P. de K. Dykes, 7.30 p.m.

Wed., Oct. 30.—EDUCATION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "The Place of Kinematics of Mechanisms in Engineering Curricula," 6.45 p.m. ★ YORKSHIRE BRANCH: George Hotel, Huddersfield, "Modern Trends in Waterworks Pumping Machinery," T. Irvine Hudson, 7 p.m.

Thurs., Oct. 31.—WESTERN A.D. CENTRE: Royal Hotel, Bristol, Address by Chairman of the Automobile Division, 6.45 p.m. ★ E. MIDLANDS GRADUATE SECTION: Gas Showrooms, New Road, Peterborough, Film Show, 7.15 p.m.

Fri., Nov. 1.—GENERAL MEETING IN CONJUNCTION WITH THE INTERNAL COMBUSTION ENGINE GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Symposium on Engine Testing, 4 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Oct. 25.—CARDIFF BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, "Management and Productivity," W. E. Gowers, 7 p.m.

Sat., Oct. 26.—NEWCASTLE UPON TYNE GRADUATE SECTION: Visit to Victor Products, Ltd., Church Bank, Wallsend upon Tyne, 10 a.m.

Mon., Oct. 28.—MANCHESTER SECTION: Reynolds Hall, College of Science and Technology, Sackville Street, Manchester, "Photography in Engineering," L. Mullins, 7.15 p.m. ★ STOKE-ON-TRENT SECTION: Grand Hotel, Hanley, Stoke-on-Trent, "Automation for Batch Production—The Role of Work Study," Ian Nickols, 7.30 p.m. ★ SOUTHAMPTON SECTION: Technical College, Portsmouth, "Contour Etching," A. W. Sheppard, 7.15 p.m.

Tues., Oct. 29.—OXFORD SECTION: North Oxfordshire Technical College, Banbury, "Properties of Pure Molybdenum Disulphide and its Application to Production Engineering," H. P. Jost, 7.30 p.m.

Wed., Oct. 30.—NORWICH SECTION: Assembly House, Theatre Street, Norwich, "The Use of Time-Lapse Photography in Work Study," A. G. Northcott, Film, "Work Study—Its Application to Team Work," 7.30 p.m. ★ SHREWSBURY SECTION: Walker Technical College, Oakengates, "Incentive Schemes," G. L. Rooke, 7.30 p.m.

Sat., Nov. 2.—BIRMINGHAM GRADUATE SECTION: Works Visit to Josiah Wedgwood and Sons, Ltd., Barlaston, Stoke-on-Trent, 10.15 a.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Oct. 25.—ORDINARY MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Rocks and Sands," S. J. Crispin, 7 p.m.

Fri., Nov. 1.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Film Evening, "Rubber in Roads" and "Rubber in Engineering," introduced by A. R. Smee, 7 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Nov. 1.—Literary and Philosophical Society, Newcastle upon Tyne, "The Marine Diesel Engine," C. C. Pounder, 6.15 p.m.

Mon., Nov. 4.—Literary and Philosophical Society, Newcastle upon Tyne, "Nuclear Power for the Propulsion of Merchant Ships," S. Livingston Smith and J. E. Richards, 6.15 p.m.

PLASTICS INSTITUTE

Tues., Oct. 29.—LONDON AND DISTRICT SECTION: National College of Rubber Technology, Northern Polytechnic, Holloway, London, N.7, "Physical Testing of Plastics," 6.30 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Nov. 5.—N.W. BRANCH: College of Technology, Sackville Street, Manchester, "Concrete Additives," M. Sandall, 6.45 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Nov. 7.—GRADUATES AND STUDENTS SECTION: 4, Hamilton Place, London, W.1, "The Background to Aircraft Specifications," K. W. Clark, 7.30 p.m.

ROYAL INSTITUTION OF GREAT BRITAIN

Fri., Nov. 1.—21, Albemarle Street, London, W.1, "Clean Air—What We Know and What We Do Not Know," Sir Hugh Beaver, 9 p.m.

ROYAL METEOROLOGICAL SOCIETY

To-day, Oct. 25.—SCOTTISH CENTRE: Department of Natural Philosophy, Drummond Street, Edinburgh, Talk on "Royal Society Base, Halley Bay, Antarctica," S. Evans, 5 p.m.

SHEFFIELD METALLURGICAL ASSOCIATION

Tues., Oct. 29.—B.I.S.R.A., Hoyle Street, Sheffield, "The Place of the Electric Steel Furnace in Present and Future Steel Production," F. T. Bagnall, 7 p.m.

SOUTH WALES INSTITUTE OF ENGINEERS

Tues., Oct. 29.—Park Place, Cardiff, Institute Centenary Celebrations, Formal opening and General Meeting, William Menelaus Memorial Lecture, "The Development of Britain's Physical and Geographical Advantages," Sir Charles Goodeve, 2.30 p.m.